

# Corrosion



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**Complete protection in a single coat—10 mils thick!**

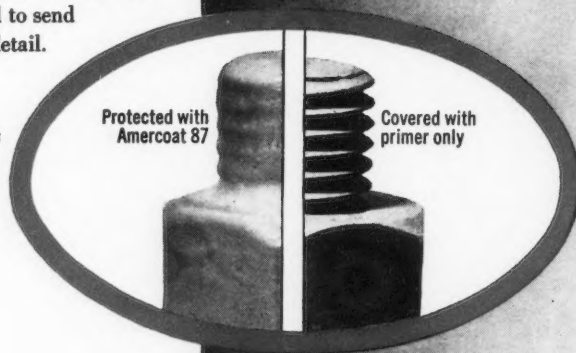
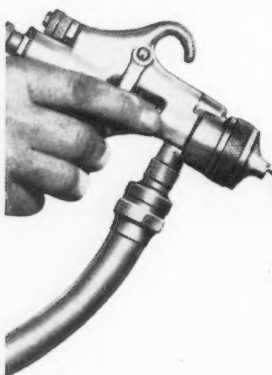
Amercoat No. 87 will cut your maintenance costs because one coat gives you the thickness and protection previously available only through the application of multiple coats.

Amercoat No. 87 is the brand new solution to an old problem, for it combines the time-tested chemical and weather resistance of a vinyl with the extra thickness that was heretofore available only in conventional mastics.

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*Notice that the sharp bolt threads, welds and sharp corners are completely protected with one coat of Amercoat No. 87—10 mils thick!*



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# a tribute to the CORROSION ENGINEER

*T*his man exists under many titles. In one plant he may be known as the Corrosion Engineer, in another the Maintenance Engineer, and in a third he may be a Metallurgist. But whatever his title, his duties are the same—he fights corrosion.

*C*orrosion Engineers work without fanfare. They fight corrosion with one or more of hundreds of materials and techniques they have in their arsenal of defenses. Their victories are quiet ones because like all preventive work, success is less conspicuous than failure.

*C*orrosion Engineers save industry many times their salaries. They reduce maintenance costs. They keep production costs down. They make possible the use of new processes and materials. They constantly improve the quality of products. All these benefits to industry are being achieved by a profession that is less than fifteen years old.

*A*mercoat Corporation knows this group of experts well, because we produce some of the corrosion resistant materials they use. We've watched them test and evaluate products and methods to make certain that only the most effective and economical are used by their companies.

*F*or this reason, we know that the achievements of the Corrosion Engineer are measured only in part by the millions of dollars he saves industry yearly. If your company employs a Corrosion Engineer, you are now receiving these direct benefits. But indirectly, everyone in America profits through his contributions to better living. This man, who is so vital to the progress of industry, deserves the full support of management.



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# announcing GALVOMAG

Dow's new high potential anode  
cuts cost of corrosion protection



4 new GALVOMAG anodes do the job of 5 conventional anodes  
... to reduce your original investment and installation cost, too

Let's take a new look at cathodic protection. Dow's new high potential anode, called GALVOMAG\*, has 25% more current output than conventional anodes.

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Your Dow anode distributor is ready with all the facts and figures on GALVOMAG. Call him today. THE DOW CHEMICAL COMPANY, Midland, Michigan.

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you can depend on DOW MAGNESIUM ANODES





THIS MONTH'S COVER—Cathodic protection and other protective measures were applied to the suspension cables in concrete deadmen at both ends of this bridge across the Rio Grande between Hidalgo, Texas and Reynosa, Tamps, Mexico. The protection applied by Corrosion Rectifying Co., Houston will prevent recurrence of the cable failure which resulted in the bridge's collapse into the river in 1939.



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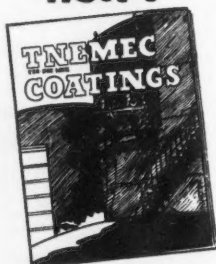
(Continued on Page 6)

*It's simple chemistry...*

# TNEMEC PRIMERS KILL RUST!

From acid (rust) condition to alkaline (NON-RUST) condition in one easy step with **TNEMEC PRIMERS!**

**HOW?**



**TNEMEC CATALOG 54 TELLS THE STORY!**

A request on your business letterhead will bring you this very useful Catalog 54.

**TNEMEC**  
TEE-NEE'-MEK

"Spell It Backwards"



**TNEMEC COMPANY, INC.**

139 W. 23rd Ave.  
North Kansas City, Mo.

## Directory of Technical Committees

(Continued From Page 5)

• **T-6A-3 Rubber, Elastomers and Heavy Linings**

H. C. Klein, Chairman, B. F. Goodrich Co., Cuyahoga Falls, Ohio.

• **T-6A-4 Vinylidene Chloride Polymers**

A. E. Young, Chairman, The Dow Chemical Co., Midland, Michigan.

• **T-6A-5 Phenolics and Furans**

Forest Baskett, Chairman, 4334 Ella Blvd., Houston, Texas.

• **T-6A-6 Polyesters**

D. F. Siddall, Chairman, The United States Stoneware Co., Box 350, Akron, Ohio.

• **T-6A-7 Fluorocarbons**

J. J. Onedreifein, Chairman, E. I. duPont de Nemours & Co., Inc., Wilmington, Delaware.

• **T-6A-8 Rigid Vinyls**

C. G. Munger, Chairman, Amercoat Corporation, 4809 Firestone Blvd., South Gate, Calif.

• **T-6B Protective Coatings for Resistance to Atmospheric Corrosion**

L. L. Sline, Chairman; Sline Industrial Painters, 2612 Gulf Terminal Drive, Houston, Texas.

Howard C. Dick, Vice Chairman, Products Research Service, Inc., Box 6116, New Orleans, Louisiana

• **T-6C Protective Coatings for Resistance to Marine Corrosion**

Raymond P. Devoluy, Chairman, The Glidden Co., Room 1310, 52 Vanderbilt Avenue, New York 17, New York.

• **T-6E Protective Coatings in Petroleum Production**

J. L. Robertson, Chairman, Phillips Petroleum Co., Bartlesville, Oklahoma

• **T-6G Surface Preparation For Organic Coatings**

S. E. Jack, Chairman, Aluminium Laboratories, Ltd., Box 84, Kingston, Ontario, Canada

S. C. Frye, Vice Chairman, Research Dept., Bethlehem Steel Co., Bethlehem, Pa.

• **Rocky Mountain Section**

• **T-6H Glass Linings And Vitreous Enamels**

G. H. McIntyre, Chairman, Ferro-Enamel Corp., Harvard & 56th Street, Cleveland 5, Ohio

• **T-6K Corrosion Resistant Construction With Masonry And Allied Materials**

L. R. Honnaker, Chairman; E. I. du Pont de Nemours & Co., Inc., Engineering Department, Louvers Building, Newark, Del.

George P. Gabriel, Vice-Chairman; Atlas Mineral Products Company, Mertztown, Pa.

• **T-6M Field Coating Inspection**

L. L. Whiteneck, Chairman, Long Beach Harbor Dept., 1333 El Embarcadero, Long Beach 2, California.

• **T-6R Protective Coatings Research**

Robert H. Steiner, Chairman, Atlas Mineral Products Co., Mertztown, Pennsylvania

## Regional and Sectional Officers—Changes

**CANADIAN REGION**

R. J. Law, Director, The International Nickel Co. of Canada, Limited, 25 King St. W., Toronto, Ontario.

L. W. Shemilt, Chairman, University of B. C., Vancouver, B. C., Canada.

T. R. B. Watson, Vice Chairman, Corrosion Service Ltd., 21 King Street East, Toronto, Ontario, Canada.

K. N. Barnard, Secretary-Treasurer, Defence Research Board of Canada, 75 Victoria Road, Dartmouth, N. S.

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F. C. Jelen, Vice-Chairman; Solvay Process Div. Allied Chemical & Dye Corp., Syracuse 1, N. Y.

J. F. Richter, Secretary-Treasurer; Delrac Corp., P. O. Box 118, Watertown, N. Y.

• **Jacksonville Section**

H. E. Alexander, Chairman, Dozier and Gay Paint Company, P. O. Box 3176, Station F., Jacksonville, Florida.

T. W. Bostwick, Vice-Chairman, City of Jacksonville, Plants Efficiency Department, Utilities Building, 34 South Laura Street, Jacksonville, Florida.

A. B. Smith, Secretary-Treasurer, Amercoat Corporation, P. O. Box 2977, Jacksonville Florida.

**NORTH CENTRAL REGION**

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William E. Kleefisch, Vice-Chairman, Nooter Corporation, 1400 S. Second St., St. Louis 4, Mo.

William J. Ries, Secretary, Tretolite Company, St. Louis 19, Mo.

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William L. Scull, Vice-Chairman; Colorado Interstate Gas Company, P. O. Box 1087, Colorado Springs, Colorado

John R. Hopkins, Secretary-Treasurer; Protecto Wrap Company, 2349 So. Delaware St., Denver, Colorado

Henry K. Becker, Trustee; Wyco Pipe Line Co., Box 2388, Denver, Colorado

• **San Francisco Bay Area Section**

Harold H. Scott, Chairman, Shell Oil Company, Martinez Refinery, Martinez, California

George J. Puckett, Vice-Chairman, Dow Chemical Company, P. O. Box 351, Pittsburgh, Cal.

William P. Simmons, Secretary-Treasurer, Alloy Steel Products Company, Inc., 24 California Street, San Francisco, Cal.

The Directory of Regional and Sectional Officers was published last in the February issue of Corrosion on Pages 4-6. The list here consists of changes and additions which have been made since that publication.



# LEAD the Imperishable Metal



Lincoln Cathedral in England, with its leaded pinnacles, gutters, parapets and roof, dates from the 12th century

*"Neither snow nor rain nor  
heat nor gloom of night stays  
these couriers from the swift  
completion of their appointed rounds"*

This well-known quotation of Herodotus' might well be paraphrased and applied to "Lead . . . the Imperishable Metal." Neither snow nor rain nor any of nature's corrosive forces—or for that matter, many of man-made—stays lead from its appointed task of protection. Whether it is in the form of white lead pigment in paint protecting buildings, red lead to protect steel construction, or pipe and sheet in acid or chemical plants, lead is the most durable of the common metals. The imperishable nature of the metal makes it possible to recover and return to the market a remarkably high percentage of the tonnage used annually. The manufacture of storage batteries is the largest consumer of lead, accounting for nearly 30% of the total, and an estimated 85% of the metal content is normally recovered for re-use within a period of two years. Moreover, the major part of all lead used in the manufacture of cable sheathing, pipe, sheet or as

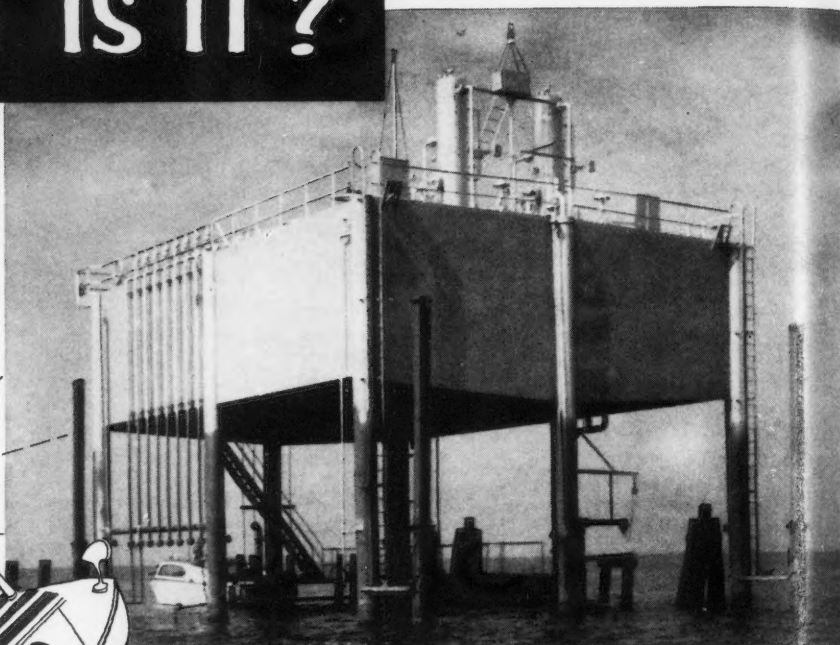
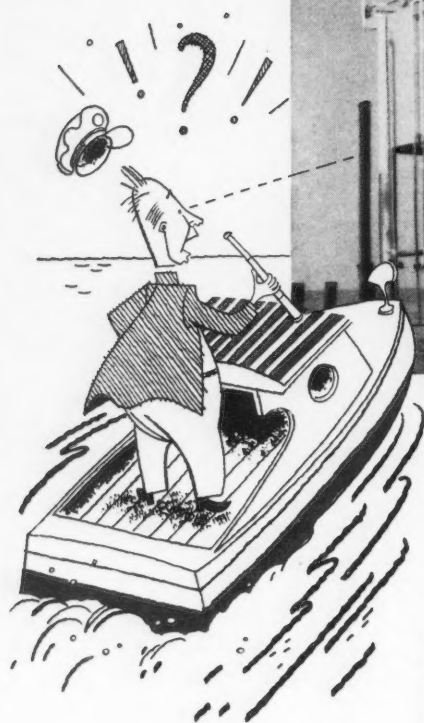
an alloy in bearing metal, solder, brass, type metal, etc., is eventually recovered.

Lead is unrecoverable only in applications where it more or less loses its identity, as in ethyl gasoline, paint, insecticides, or where recovery is either impossible or impractical, as in ammunition, foil orterne plate. In all other applications, lead is eventually recovered and an estimated 45% of the total annual consumption is ultimately reclaimed for use.

It has aptly been said that one of the greatest reserves of lead in the world is the incalculable tonnage tied up in the U. S. industrial system — the potential source of scrap and secondary metal. This is an important consideration in estimating the cost of long range projects, as the lead used will have a definite market value when the metal is eventually reclaimed and may be resold to perform its useful work again.

**ST. JOSEPH LEAD COMPANY**  
250 PARK AVENUE • NEW YORK 17  
Eldorado 5-3200  
THE LARGEST PRODUCER OF LEAD IN THE UNITED STATES

# WHAT IS IT?



## An off-shore oil tank coated with **INSUL-MASTIC!**

Thirteen miles off the shore of Corpus Christi stands this oil storage tank. An island on legs receiving oil from eight off-shore drilling rigs. The water is shallow, the heat and humidity are terrific. Evaporation is rapid and the atmosphere is among the saltiest and most corrosive on earth. That is why the sides and bottom of the island tank are coated with INSUL-MASTIC.

INSUL-MASTIC's heavy, reinforced asphaltic coatings also prevent corrosion in steel mills, paper pulp mills, chemical plants and other industries where the corrosive atmosphere is extremely severe. Claims and appearances can be duplicated, but INSUL-MASTIC's record for maintenance-free protection shows jobs 12, 15 and 20 years old . . . and that record cannot be duplicated.

To prevent corrosion in your plant, specify the protective coating which has stood the test of time. Specify INSUL-MASTIC and free yourself of corrosion and maintenance.

**INSUL-MASTIC** coatings are made only in the **INSUL-MASTIC** laboratories from a number of raw materials, each carefully selected for a particular function or quality. Among these are asphalt and Gilsonite.

# Insul-Mastic



*Think first of the  
coatings that last!*

Representatives in Principal Cities

CORPORATION OF AMERICA • OLIVER BUILDING, PITTSBURGH 22, PA.

KEL-F Plastic co  
owers to plant e  
lems. This fluoro  
virtually all che  
mineral acids, ox  
strong caustics.

### HIGH COMPRESS

KEL-F Plastic is  
ency and resist  
seals and gaskets  
exhibit a low pe  
under load — ret  
more effectively.

### RESISTANCE TO

KEL-F Plastic h  
ance to tempera  
satisfactory prop  
range of approxi  
to 390° F.)

### NON-ADHESIVE

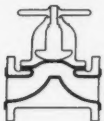
The non-adhesiv  
Plastic are advan  
of viscous fluids,  
unclogged lines an

**WHEN FLUIDS ARE**  
.....

# TOO ROUGH FOR METAL!

## Get the Certain Protection of **KEL-F® Plastic**

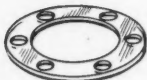
**in Valve Linings**



**Valve Diaphragms**



**Gaskets**



**O-Ring Seals**



KEL-F Plastic can supply many of the answers to plant equipment corrosion problems. This fluorocarbon plastic is inert to virtually all chemical attack — including mineral acids, oxidizing agents as well as strong caustics.

### **HIGH COMPRESSIVE STRENGTH**

KEL-F Plastic is outstanding for its resiliency and resistance to cold flow. Ring seals and gaskets molded of KEL-F Plastic exhibit a low percentage of deformation under load — retaining seals longer and more effectively.

### **RESISTANCE TO HEAT AND COLD**

KEL-F Plastic has unusually high resistance to temperature extremes — exhibits satisfactory properties over a temperature range of approximately 710° F. (—320° F. to 390° F.)

### **NON-ADHESIVE**

The non-adhesive properties of KEL-F Plastic are advantageous in the handling of viscous fluids, and in maintaining clean, unclogged lines and equipment.

### **MOLDABILITY**

KEL-F Plastic is readily molded—by injection compression or extrusion. Its dimensional stability and low mold shrinkage make it ideally suited to molding with metal. The techniques of molding this fluorocarbon have been fully developed, and perfected. Today, KEL-F Plastic parts and products are produced in volume by molders throughout the country.

Modern processing methods demand plant equipment with greater resistance to corrosion, temperature extremes and higher pressures. The weak links in such equipment are the valves, gaskets and seals. KEL-F Plastic is providing the solution to many of these problems, and producing demonstrable results in reduced downtime and lowered maintenance costs. It is available as a molding compound, or it can be obtained in rods, tubing, sheets and film from a number of suppliers. It is also available in dispersions, suitable for bake-coating on metals and certain non-metals. The full story of KEL-F Polymer should be in your active file. Write us.



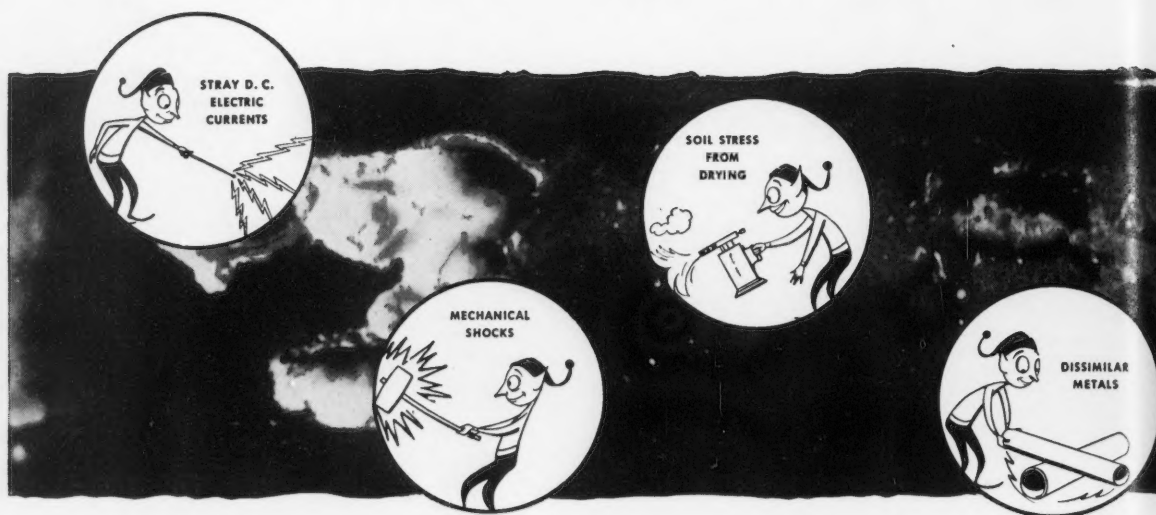
**THE M. W. KELLOGG COMPANY**

Chemical Manufacturing Division  
P. O. Box 469, Jersey City, N. J.  
SUBSIDIARY OF PULLMAN INCORPORATED

© Registered trademark of The M. W. Kellogg Company's fluorocarbon polymers.



# 6 DRESSER PRODUCTS THESE MAJOR CAUSES



## ***Gas Men Seek Improved Insulating Methods ... Help Develop Dresser Insulating Products***

Whenever utility men get together, corrosion almost always heads the list for discussion—how to best protect their company's huge investment in underground piping. Satisfied that insulated pipe effectively resists corrosion, they are naturally interested in talking over improved insulating methods, new insulating applications.

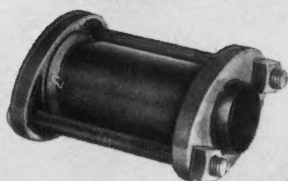
Having pioneered the insulated pipe joint, over 50 years ago, Dresser can draw on a reservoir of experience in corrosion protection to better serve the industry: Working closely with gas engineers and superintendents, Dresser Corrosion Laboratories have, since that time, developed many effective methods of insulating against corrosion. These have resulted in today's wide variety of Dresser Insulating Products—each designed to meet a specific need in protecting pipe and pipe joints.

**For Complete Details on How You Can Get More Effective, Economical Corrosion Protection, Send for Dresser Corrosion Control Catalog**

\*INSULOK and DRESSERTAPE are trade-marks of Dresser Mfg. Div.

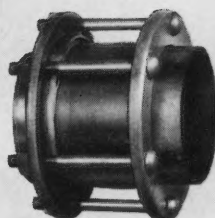
**DRESSER® CORROSION  
CONTROL PRODUCTS**

# TO HELP YOU FIGHT OF PIPE CORROSION!



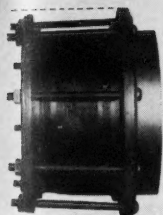
## INSULATING COUPLINGS STYLE 39

Basically the same design as the well-known Dresser Style 38 Coupling, the Style 39 has rubber insulating gaskets compounded to assure optimum insulation and long life. The tough, inert polyethylene skirt is immune to acids, alkalies, drip oils . . . will not swell.



## INSULATING-REDUCING COUPLINGS • STYLE 39-62

This combination insulating and reducing coupling eliminates the danger of corrosion from joining dissimilar metals. The insulating gasket is supplied as standard on the cast-iron pipe end. A polyethylene skirt separates and insulates the pipe ends.



## INSULOK\* ADAPTERS STYLE 90

This new insulating connector is made to order for setting gas meters and regulators—a virtually tamper-proof fitting which resists pull-out from the unusual strains often put on service line piping.

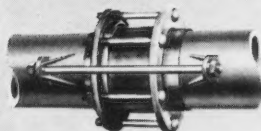


## INSULATING SERVICE LINE FITTINGS STYLE 90



These small diameter insulating couplings and fittings provide fast joining of service piping up to 2", plus permanent corrosion protection. Both the nut and fitting body are insulated from the pipe.

## INSULATING JOINT HARNESSES



Used in conjunction with Dresser Insulating Couplings, at bends and other points of stress, these harnesses restrict pipe movement at the joint, while preventing "by passing" current flow through the lugs and harness bolts.

## DRESSERTAPE\*



A high dielectric plastic pipe tape providing positive electrical insulation, while protecting underground pipe against salt water, soil chemicals, acids, alkalies and oil. Available in 10 and 20 mil thicknesses, all standard widths.

## DRESSER MANUFACTURING DIVISION

(One of the Dresser Industries)

89 Fisher Ave., Bradford, Pa. Warehouses: 1121 Rothwell St., Houston; 101 S. Airport Blvd., S. San Francisco. Sales offices also in: New York, Philadelphia, Chicago, Toronto.

## a hundred mile investment...



**is worth  
protection**

And Kontol offers the best. Whether your pipe lines are measured in miles, hundreds of miles or thousands of miles—corrosion, fouling and scaling are potential hazards. Kontol inhibitors offer proved protection against corrosion; they also have effective detergent characteristics which have demonstrated outstanding line-cleaning action.

A typical case in point was a 385 mile, 6" product line in the eastern area, originally designed to handle 12,000 bpd. After preliminary scraping to remove loose scale, Kontol 118 was injected at the rate of one gallon per thousand barrels of throughput. Shown below is a summary of the results obtained.

LINE	"C" FACTOR	
	BEFORE KONTOL*	AFTER KONTOL**
Pump Station 2 to 3	132	138
Pump Station 3 to 4	135	142
Pump Station 4 to 5	138	145
Pump Station 8 to 9	118	135

\*Scrapers only

\*\*Kontol and scrapers

THROUGHPUT INCREASE: 720 barrels per day  
ESTIMATE SCALE REMOVED: 16 tons

After the line was cleaned, Kontol 77 was injected into the line to control acidic corrosion and oxidation. This treatment will also aid in maintaining a high "C" factor.

Laboratory tests have conclusively proved that Kontol 118 and Kontol 77, at concentrations of one gallon per thousand barrels of hydrocarbon, have no detrimental effect on product quality.

For complete information on how Tretolite Company products and services can help you protect your pipeline investment, call your Tretolite service engineer, or write to

### TRETOLITE COMPANY

A DIVISION OF PETROLITE CORPORATION

369 Marshall Avenue, St. Louis 19, Missouri

5515 Telegraph Road, Los Angeles 22, California



Chemicals and Services for the Petroleum Industry

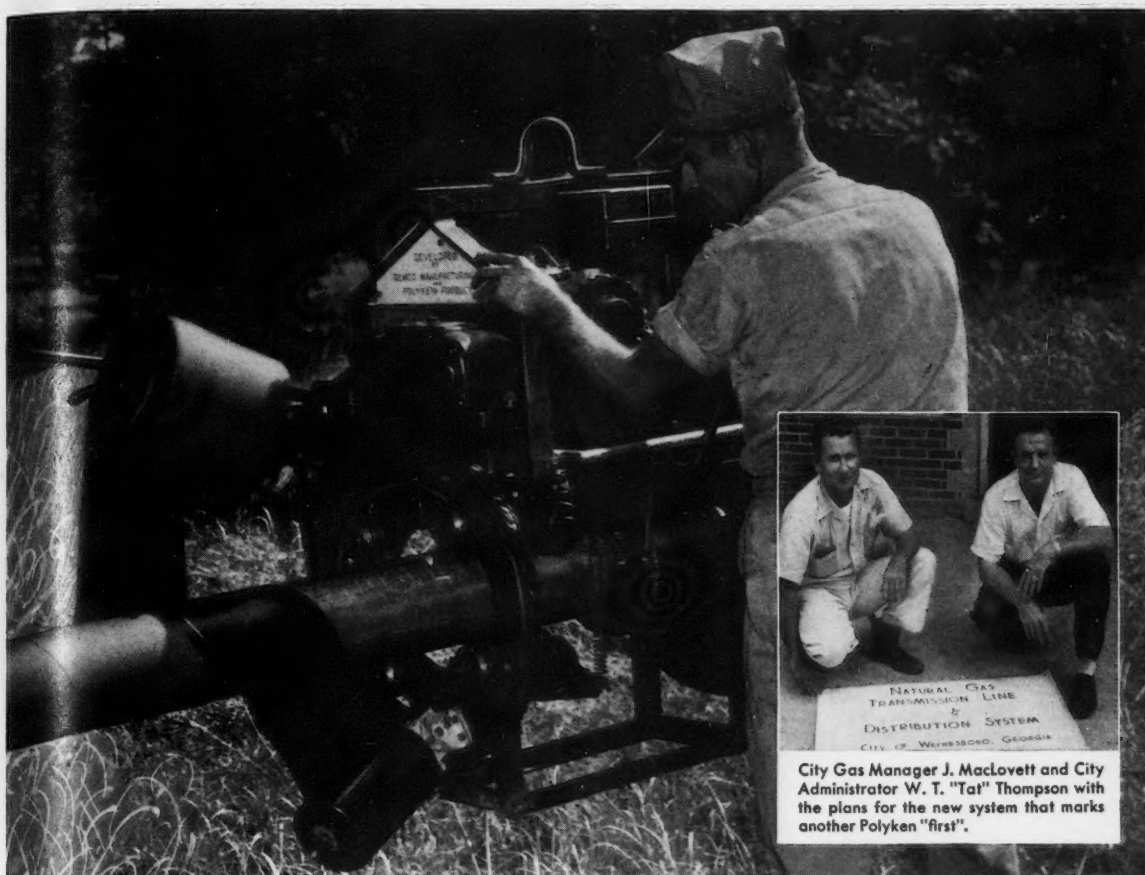
DESALTING • SCALE PREVENTING • WATER DE-OILING • PRODUCTION STIMULATION  
DEMULSIFYING • PARAFFIN REMOVING • CORROSION INHIBITING • BACTERICIDES

8K PL 55-18

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There a  
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—but th  
Polyken

PRO  
Polyken





City Gas Manager J. Maclovett and City Administrator W. T. "Tat" Thompson with the plans for the new system that marks another Polyken "first".

## Polyken<sup>®</sup> Protective Coating used for the nation's first complete tape-wrapped gas system at Waynesboro

There are 42 miles of pipe in the Waynesboro, Georgia, new natural gas system—and it's all protected from corrosion damage by Polyken No. 900 Protective Coating. Here, for the first time, high-speed power taping equipment was used.

That makes history—this is the first complete tape-wrapped system—but this is not an experiment. Polyken has already proved what it

can do in both the laboratory and the field. The Waynesboro installation brings out all the advantages of this tough, durable polyethylene protection.

Polyken is manufactured from controlled raw materials under controlled conditions. The thickness and composition is consistently accurate. The contractor has no quality control problems.

Polyken is applied right off the roll—without heat, liquids, solvents or thinners. That saves time and labor costs.

The resistance of Polyken to galvanic, water and chemical corrosion doesn't vary. It resists bacterial and fungus growth. It has high dielectric strength.

Get the complete story. Send in the coupon.

# Polyken<sup>®</sup>

**CONTROLLED STRENGTH**

## PROTECTIVE COATINGS

Polyken Products Department of The Kendall Company

Polyken, Dept. C-C

222 West Adams St., Chicago 6, Illinois

Please send me complete details of the Waynesboro Installation and samples and further information on Polyken Protective Tape Coatings.

Name \_\_\_\_\_ Title \_\_\_\_\_

Company \_\_\_\_\_

Street Address \_\_\_\_\_

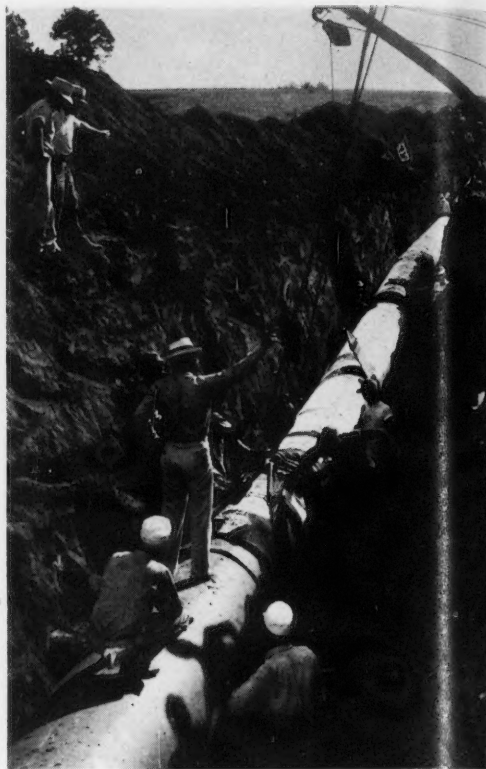
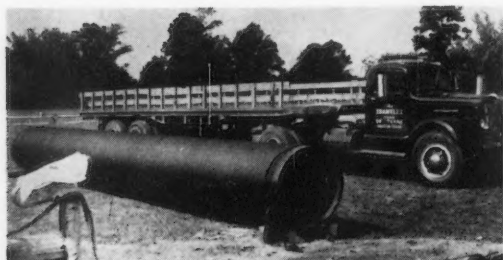
City \_\_\_\_\_ Zone \_\_\_\_\_ State \_\_\_\_\_

## FACTS that prove

**Enamel-X**  
PIPE ENAMELS & PRIMERS

### SUPERIOR to other Enamels!

1. Enamel-X enamels have lower specific gravities than other types of enamels; thus, they will give greater coverage of the same thickness for the same weight of material.
2. Enamel-X enamels have greater resiliency than other types of enamels, that is, greater ability to return to their original position after stress.
3. Enamel-X enamels have less wastage during storage and are easier to handle after storage than other types due to less plastic flow.
4. Results of sag tests, cold tests, and peel tests of Enamel-X enamels are superior to test results of any of the other types of enamels.



TYING IN A ROAD CROSSING in Alabama, where Enamel-X was used on one of the largest gas pipe lines ever laid.

The same top-quality coating job was obtained on this large size pipe as was obtained on smaller sizes pipes. The left top photo shows a close-up of a completed joint (coated) prior to its installation.

With no danger of plastic flow due to heat, Enamel-X can be stacked in the open like cordwood and left indefinitely. Enamel-X is easily handled on both over-the-ditch and yard coating jobs—the cartons are easily loaded and unloaded and the treated cardboard wrap is readily removed prior to the coating operation.

**FOR FURTHER INFORMATION  
SEE YOUR NEAREST  
B-K REPRESENTATIVE**



**Brance-Krachy Co. INC.**

4411 NAVIGATION • P.O. Box 1724 • HOUSTON

FOR FULL INFORMATION WRITE, WIRE OR TELETYPE (HO-561)

**CO  
HA**

A chemi  
Sodium  
sives for  
To handl  
acids, th  
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policy is  
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(1)—Not  
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**US  
RUBB**

Hose • Re  
Molded and



Photo shows inspector examining Uscolite pipe lines on vacuum boxes in plant. Lower illustration shows 2" discharge line from a plate and frame polishing press in same plant. Engineers are comparing the clean lines of Uscolite pipe and Uscolite Hills-McCanna valve with the corroded metal pipe at the left.

## HERE'S PROOF CORROSION DOES NOT HARM U. S. USCOLITE PIPE



### Read what this plant discovered about U. S. Uscolite®

A chemical processing company\* in Michigan makes Mono Sodium Glutamate (MSG) in bulk. By-products are adhesives for cigarette papers, wallpaper sizing and allied items. To handle the highly corrosive raw and dilute hydrochloric acids, this plant began to use U.S. Uscolite Pipe 5 years ago. The results were so impressive that the company's policy is now to replace only with U. S. Uscolite Pipe. The milling company found that:

(1)—Not one single length of U. S. Uscolite Pipe has yet failed from corrosion. The plant capacity is 12 million lbs. of MSG a year.

(2)—Not one single length of Uscolite has failed from impact

shock or any other reason.

(3)—Although temperature ranges from 150° to minus 10° F, these extremities of temperature have had absolutely no effect on Uscolite Pipe.

(4)—Uscolite is easier to handle because it weighs less. It is cut to length and threaded on the job. Its great impact strength prevents breakage.

A development of United States Rubber Company, Uscolite pipe and fittings provide a corrosion-resistance and a stamina never before obtainable in piping. Place your order for Uscolite pipe and fittings with any of our 27 District Sales Offices or write address below.

\*The Huron Milling Company.



"U. S." Research perfects it... "U. S." Production builds it... U. S. Industry depends on it.

**UNITED STATES RUBBER COMPANY**  
MECHANICAL GOODS DIVISION • ROCKEFELLER CENTER, NEW YORK 20, N. Y.

Hose • Belting • Expansion Joints • Rubber-to-metal Products • Oil Field Specialties • Plastic Pipe and Fittings • Grinding Wheels • Packings • Tapes  
Molded and Extruded Rubber and Plastic Products • Protective Linings and Coatings • Conductive Rubber • Adhesives • Roll Coverings • Mats and Matting



# THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

- (a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.
- (b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.
- (c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.
- (d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.
- (e) To promote standardization of terminology, techniques, equipment and design in corrosion control.
- (f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.
- (g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.
- (h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 1061 M & M Building, No. 1 Main Street, Houston 2, Texas.



## Officers, 1954-55

<i>President</i> .....	AARON WACHTER
	Emeryville, California
<i>Vice-President</i> .....	FRANK L. WHITNEY, JR.
	St. Louis, Missouri
<i>Treasurer</i> .....	R. A. BRANNON
	Houston, Texas
<i>Executive Secretary</i> .....	A. B. CAMPBELL
	1061 M & M Building, Houston 2, Texas

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AARON WACHTER .....1954-55  
Shell Development Co., Emeryville, California

### Vice-President

FRANK L. WHITNEY, JR. ....1954-55  
Monsanto Chemical Co., St. Louis, Missouri

### Treasurer

R. A. BRANNON .....1954-55  
Humble Pipe Line Company, Houston, Texas

### Past President

WALTER F. ROGERS .....1954-55  
Gulf Oil Corporation, Houston, Texas

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New York, N. Y.

W. F. FAIR, JR. ....1953-56  
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ROBERT L. BULLOCK .....1953-56  
Interstate Oil Pipe Line Co., Shreveport, La.

NORMAN HACKERMAN .....1952-55  
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### Representing Corporate Membership

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H. R. BROUGH .....1954-57  
Mountain Fuel Supply Co., Salt Lake City, Utah

P. H. SMITH .....1953-56  
Nooter Corporation, St. Louis, Mo.

H. P. GODARD .....1952-55  
Aluminium Laboratories, Ltd., Kingston, Ontario

V. V. KENDALL .....1952-55  
United States Steel Corp., Pittsburgh, Pa.

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Alloy Steel Products Co., Inc., Atlanta, Ga.

G. E. BEST ..... (Northeast) 1954-57  
Mutual Chemical Co. of America, Baltimore, Md.

WALTER R. CAVANAGH .. (North Central) 1953-56  
Parker Rust Proof Company, Detroit, Michigan

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## Rigid PVC as a Construction Material For Valves

By ROLLAND McFARLAND, JR.\*

THE SO-CALLED, rigid polyvinyl chloride resins (PVC) originated from French and German plastics technology and their use in the chemical industries in these countries became relatively commonplace due to the shortage of critical materials of construction at the time of World War II.

It was found that by careful control of the polymer size of the polyvinyl chloride a molding resin could be produced which with proper molding techniques would form a tough, stable and rigid article, without the necessity of adding fillers or modifiers such as plasticizing agents. At the same time the molded article was not brittle, but was tough and workable. For example, in France, the material was produced and exported under the name Lucoflex and some of the German resin also was imported into the United States and sold for chemical construction use.

Ultimately American resin manufacturers utilized the special polymerization technique required for control of molecular size and now there are a number of such resins on the market carrying well known trade names. The particular modern modification of these resins to the high impact type is an American development, which permits manufacturing a high impact resin for use where such a material is required.

The unmodified polyvinyl chloride resins must be as free as possible of processing modifiers in order to achieve the maximum corrosion resistance. A surprisingly small amount of extraneous material will greatly reduce the chemical resistance and any attempt to modify the material through the small additions of plasticizer and adulterants only results in lowering physical qualities and chemical resistance properties. Actually, the commercial PVC or unplasticized compounds contain the absolute minimum in lubricant, stabilizer and colorant to achieve processing quality and yet maintain the highest chemical resistance and optimum physical properties obtainable from this particular molecular weight range of the polyvinyl chlorides.

The physical properties of most of these resins are

\*Hills-McCanna Company, Chicago, Ill.



Figure 1

available in commercially published charts and listed below are a few of the important physical specifications for reference purposes:

### Physical Properties

Specific Gravity .....	1.40
Tensile Strength in PSI.....	8300
Rockwell Hardness .....	R107 to R110
Heat Distortion in Degrees Centigrade.....	75
Izod Impact, Foot Pounds per square inch....	1.80
Flexural Modulus in PSI.....	$4.7 \times 10^8$
Flammability ASTM-(D568-48) ..	Self Extinguishing

The physical properties of the high impact type PVC resins differ somewhat in that there is somewhat less hardness, a small drop in tensile strength and an increase in the impact resistance to 12 to 15 foot pounds per inch (unnotched). The chemical resistance of the high impact type resins is slightly less with reference to some of the reagents which are borderline applications with PVC.

These resins are useful to minus 40 F, providing,

of course, that they are protected from shock or sudden load which might tend to break them. At minus 40 F the impact resistance of the high impact type resin is reduced to approximately 0.8 foot pounds per inch.

This material lends itself to ready fabrication into pipe, fittings and valves such as is illustrated in the accompanying Figure 1. This illustrates a diaphragm type valve of a well known design, wherein the valve body is of rigid PVC, the diaphragm is of Teflon, Polyethylene, rubber, Neoprene or other elastomer and with the standard operating bonnet assembly which actuates the diaphragm to open, throttle or close the valve.

The valve with the standard pipe and fittings is supplied, in sizes  $\frac{1}{2}$  to 2 inches, in the screwed end connection. In making up such joints, it is essential that care be utilized not to start a cross thread, nor to pull them up too tightly. It also is recommended that a lubricant be used that is resistant to the chemical reagents being handled, although the pipe joint can be made up without the use of a thread lubricant. This type of resinous material does not suffer from droop or excessive cold flow but being a non-metallic material, it is suggested that the entire piping system be properly supported for maximum effective use.

Maximum operating temperature of rigid PVC is approximately 150 F. It is not recommended that these materials be used at high temperatures. Of course, there are always peculiar circumstances in

which components of the material, unstressed may operate at higher temperatures, but the consensus on maximum operating temperatures is 150 F.

Working pressure for the material in valve and fitting form is 150 psi at 70 F, for sizes up to and including the 2-inch size. At 150 F the working pressure is 150 psi for the  $\frac{1}{2}$ -inch size decreasing to 75 psi where the sizes increase to 2 inches.

Rigid PVC is widely used in this country for chemical service construction. The material has been very satisfactorily used on dry and wet hydrogen chloride, nitric, sulfuric and hydrofluoric acid, or mixtures of these acids; and also for handling concentrated nitric acid and vapors from concentrated nitric acid. It has also been very satisfactorily used on hydrogen peroxide, sulfur dioxide, sulfur trioxide and for sodium hydroxide service. It has also been used in plating plant work and handling successfully such material as sugar juices, sour milk, low beer, low wine, vinegar, pharmaceutical preparations, distilled water and chlorine solutions.

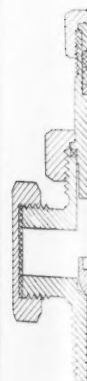
Rigid polyvinyl chloride is not recommended for use with most organic chemical material such as esters, aromatic hydrocarbons, ethers, ketones, chlorinated hydrocarbons, heterocyclics and similar materials. The chemical resistance properties of rigid polyvinyl chloride are becoming increasingly well known and detailed specifications from resin suppliers are available.

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# Minimizing Stress Corrosion Cracking Of Cylinder Valves\*

By M. SCHUSSLER\*

## INTRODUCTION

**F**ORGED ALUMINUM bronze valves, used for handling corrosive gases in cylinders under conditions where high pressures might be encountered were found to be susceptible to failure. Owing to the nature of the cylinder contents, such failures can be accompanied by a high order of hazard to personnel and can result in costly losses of materials and equipment. Some valves failed in service by developing longitudinal splits in the bonnets. The valves under consideration were of the design shown in Figure 1 and failed under exposure conditions involving corrosive gases on the internal surfaces and steam and atmospheric impurities on the external surfaces.

An examination was made on several valves to determine the cause of the bonnet failures and stress corrosion tests were conducted on new valves to determine if remedial measures might be found which would minimize the possibility of future failures.

## Examination of Failed Bonnets

The bonnet material was a two phase, forged or extruded aluminum bronze corresponding to Federal Specification QQB 666, Grade B (nominal composition of 9 percent aluminum, 1 percent iron). A representative failure of the type experienced is shown in Figure 2. Cross sections through the failures showed that the path of fracture was intergranular and was typical of stress corrosion failures (Figure 3). The bonnets (hardness of Rockwell B 85) had a two phase structure of alpha plus eutectoid, with the eutectoid dispersed in long, longitudinal stringers (Figure 4).

\*Submitted for publication September 10, 1954.

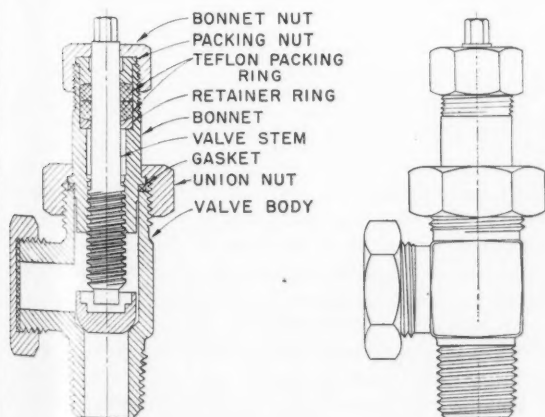


Figure 1—One-inch 2-piece cylinder valve.

## Abstract

This investigation covers the diagnosis of the cause of splitting of aluminum bronze bonnets on valves for cylinders for handling corrosive gases and the remedial steps taken to minimize the failures.

The splits in the bonnets were found to be due to stress corrosion cracking which was induced by excessive torque applied to the bonnet, by a design weakness in bonnet itself and by the presence of longitudinal stringers of eutectoid in the material.

Laboratory tests showed that design changes could be made to strengthen the bonnets and that the stringers could be eliminated by heat treatment. The combination of heat treated bonnets, along with controlling torque applied to the bonnet nuts, eliminated bonnet failures in the valves. Improvements in bonnet design were incorporated in a new design for valves.



Figure 2—Typical stress corrosion failure in a bonnet from a cylinder valve.



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Propagation of the fracture in a longitudinal direction was suspected to have been facilitated by the stringers of the second phase in the material. This contention was verified in stress corrosion tests. In the test results the longitudinal splits which developed in the bonnets followed the stringers (Figure 5); even when circumferential ruptures were produced under certain stress corrosion testing condi-

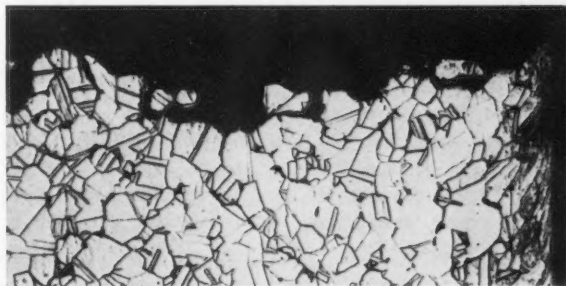


Figure 3—Cross section through rupture in bonnet from a cylinder valve. Structure near outer surface. Intergranular path of fracture is typical of failures attributed to stress-corrosion cracking. Etchant; Potassium dichromate. X 200.

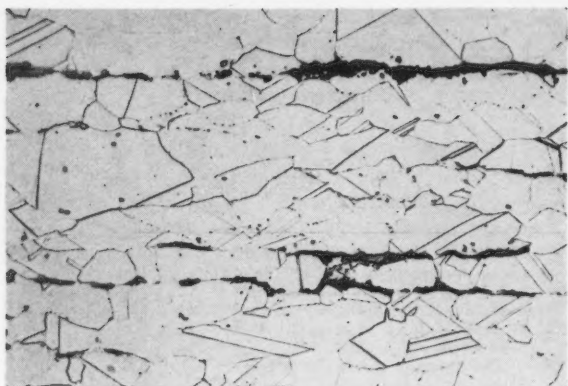


Figure 4—Longitudinal cross section showing typical structure in as received QJB 666 bonnets. Structure consists of alpha phase and stringers of eutectoid and has a hardness of Rockwell B85. Etchant: Ammonium hydroxide, hydrogen peroxide. X 250.

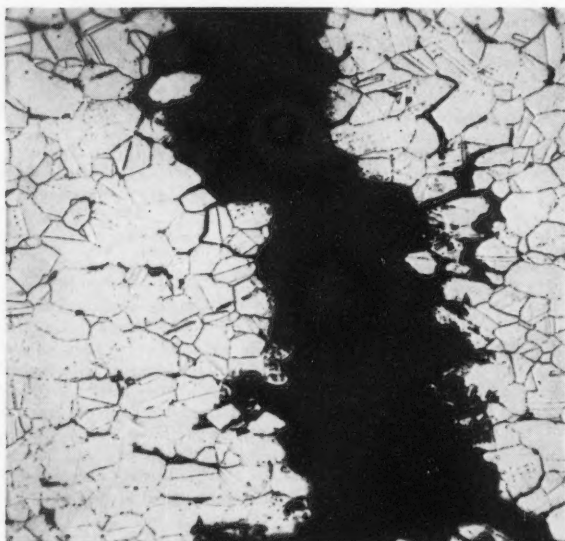


Figure 5—Cross section through longitudinal stress corrosion crack in a valve bonnet. This failure was produced in a stress corrosion test with bonnet tested in original design and with low torque applied to bonnet nut. Etchant: Ammonium hydroxide, hydrogen peroxide, followed by ferric chloride. X 250.

tions, branch cracks sought out the eutectoid stringers although the stringers were oriented transversely to the direction of crack propagation (Figure 6).

#### Remedial Treatment of Bonnets

Findings on the bonnet failures indicated that if the stringers of eutectoid were eliminated, or if the eutectoid was randomly distributed, then the valve bonnets would be less susceptible to failure. In an effort to eliminate the eutectoid stringers present in the as received bonnets, a two step heat treatment was selected as follows:

1. Transform the original alpha plus eutectoid structure to the beta phase by heating for ten minutes at 1750F and water quench to retain the beta structure.
2. Reheat to 1110F, hold for four hours to trans-



Figure 6—Cross section through circumferential stress corrosion crack in a valve bonnet. This failure was produced in a stress corrosion test with packing arrangement modified to simulate modified design and with high torque applied to bonnet nut. Etchant: Ammonium hydroxide, hydrogen peroxide followed by ferric chloride. X 250.

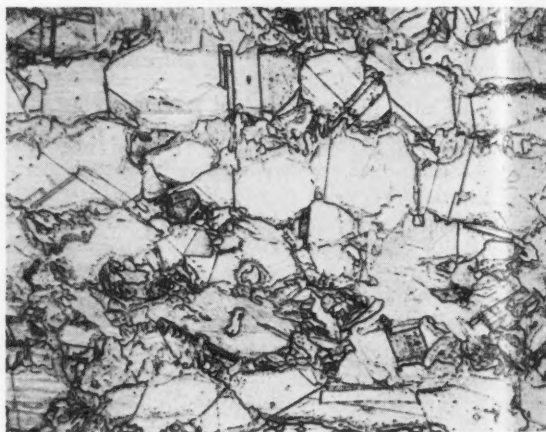


Figure 7—Longitudinal cross section showing typical structure in heat treated QJB 666 bonnets. Structure consists of alpha phase and dispersed eutectoid and has a hardness of Rockwell B65. Etchant: Ammonium hydroxide, hydrogen peroxide followed by ferric chloride. X 250.

form most of the beta phase to alpha phase and slow cool to permit gradual transformation of the remaining beta to alpha plus eutectoid.

The structure of the bonnets after heat treatment is shown in Figure 7. The structure (hardness of Rockwell R 65) has more alpha and less eutectoid than the as received structure. Furthermore, the eutectoid in the heat treated bonnets appears to be distributed randomly to a reasonable extent.

In order to evaluate the effects of the heat treatment, stressed valve bonnets in both the as received and the heat treated conditions were subjected to accelerated stress corrosion tests in mercurous nitrate solution. The tests were performed according to the standard mercurous nitrate method (ASTM Design-

TABLE 1-

Test No.	Cond. Ma
1	As rec
2	As rec
3	As rec
4	As rec
5	As rec
6	As rec
7	As rec
8	As rec
9	Heat
10	Heat
11	Heat
12	Heat
13	As rec
14	As rec
15	As rec
16	As rec
17	As rec
18	As rec
19	As rec

\* The bon alloy.

Result On Cylind

Test No.

20	.....
21	.....
22	.....
23	.....
24	.....
25	.....
26	.....

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TABLE 1—Results of Mercurous Nitrate, Stress Corrosion Tests on Cylinder Valves\*

Test No.	Condition of Material	Test Conditions	Torque Applied to Bonnet Nut, Ft.-Lb.	Exposure Time (Min.) When Cracking First Observed	Remarks
1	As received	Bonnet tested separately	None	Did not fail	No cracks in 15 minutes.
2	As received	Bonnet tested separately	None	Did not fail	No cracks in 15 minutes.
3	As received	Bonnet tested separately	None	Did not fail	No cracks in 15 minutes.
4	As received	Bonnet tested separately	None	Did not fail	No cracks in 15 minutes.
5	As received	No modification to packing	20	3	Single longitudinal crack in bonnet.
6	As received	No modification to packing	20	7-10	Single longitudinal crack in bonnet.
7	As received	No modification to packing	20	3	Single longitudinal crack in bonnet.
8	As received	No modification to packing	40	1-2	Several longitudinal cracks in bonnet, bonnet nut cracked also.
9	Heat treated	No modification to packing	40	—	No cracks in 15 minutes.
10	Heat treated	No modification to packing	60	—	Bonnet nut cracked but bonnet had not cracked in 15 min.
11	Heat treated	No modification to packing	60	—	No cracks in 15 minutes.
12	Heat treated	No modification to packing	80	—	Bonnet nut cracked, but bonnet had not cracked at end of 15 minutes. The bonnet did crack at root of threads after several hours.
13	As received	Bonnet nut moved downward so that packing was partly within the bonnet nut.	40	2½	Several longitudinal cracks in bonnet.
14	As received	Bonnet nut moved downward so that packing was partly within the bonnet nut.	80	2	Several longitudinal and radial cracks in bonnet.
15	As received	Bonnet nut moved downward and packing moved upward so that packing was entirely within bonnet nut.	20	Did not fail	No cracks in 15 minutes.
16	As received	Bonnet nut moved downward and packing moved upward so that packing was entirely within bonnet nut.	20	Did not fail	No cracks in 15 minutes.
17	As received	Bonnet nut moved downward and packing moved upward so that packing was entirely within bonnet nut.	40	Did not fail	No cracks in 15 minutes.
18	As received	Bonnet nut moved downward and packing moved upward so that packing was entirely within bonnet nut.	40	Did not fail	No cracks in 15 minutes.
19	As received	Bonnet nut moved downward and packing moved upward so that packing was entirely within bonnet nut.	80	10	Bonnet nut cracked, but bonnet did not.

\* The bonnet of the valve is made from QQB 666 alloy while the bonnet nut is made from Duronze III alloy.

TABLE 2  
Results of Simulated Service Tests in Saturated Steam  
On Cylinder Valves With As Received Heat Treated Bonnets

Test No.	Condition of Bonnet	Torque Applied to Bonnet Nut, Ft. Lb.	Test Results
20	As received	40	No cracks
21	As received	80	No cracks
22	As received	120	Bonnet cracked
23	As received	80	No cracks
24	As received	100	Bonnet cracked
25	As received	120	Bonnet cracked
26	Heat treated	145	No cracks

nation: B 154-45). It should be emphasized that the mercurous nitrate test is very severe, but is useful in indicating the trend of susceptibility toward stress corrosion failure. Results from these tests, such as torque values, cannot be applied directly to other corrosive environments, i.e., to conditions of service.

Samples were examined during the tests for evidence of cracks after exposure times of ½, 1, 1½, 2, 2½, 3, 4, 5, 7, 10, 12, and 15 minutes. The results of the mercurous nitrate tests are given in Table 1 and demonstrate the improvement resulting from the heat treatment.

Tests 1 through 4 were run on the bonnets only. Since no cracking occurred, it was indicated that the material in the as received condition was not sensitive

to stress corrosion cracking if no external stress was applied. The bonnets with the as received structure failed by stress corrosion cracking with torques on the bonnet nut of less than 20 foot-pounds (tests 5 to 8) while the heat treated bonnets successfully withstood stresses corresponding to 60 to 80 foot-pounds torque on the bonnet nut (tests 9 to 12).

Simulated service tests were conducted in which valves were assembled with various torques on the bonnet nut and subjected to exposure to a saturated steam atmosphere for 48 hours. The assembly torques that were used and the test results are presented in Table 2. The bonnets with the as received structure failed by stress corrosion cracking with a torque of 100 ft.-lb. applied on the bonnet nut (Test 24). One heat treated bonnet was subjected to the saturated steam test but did not fail at an applied torque of 145 ft.-lb.; nor did it fail when allowed to cool and then stressed to 170 ft.-lb. torque (Test 26). The valve then was disassembled and placed in a mercurous nitrate bath to test for residual stresses but no failure occurred.

### Design Considerations

Arrangement of the valve stem packing under consideration is shown in the sketch in Figures 1 and 8. With this design, the Teflon packing is forced radially against the valve stem and the bonnet (QQB 666 alloy) as the bonnet nut (Duronze III alloy) is tightened. The bonnet nut does not overlap or reinforce the bonnet in the area where the packing is exerting outward pressure. The thickness of the bonnet at this area is only about 0.085-inch, from the root of the thread to the outer surface. Because of the force exerted by the packing and because of the thin wall of the bonnet, the bonnet tends to become bulged by the high stresses induced in it when the bonnet nut is torqued.

It appeared that the bonnet could be protected from excessive stresses by:

- increasing the wall thickness of the bonnet, and
- modifying the design of the bonnet so that the area of the bonnet on which the packing exerts radial force is contained between the packing and the bonnet nut.

This would tend to reduce the tensile stresses in the bonnet to a lower level than in the original design. These possible modifications to the valve are shown in Figure 8. It also would be expected that there



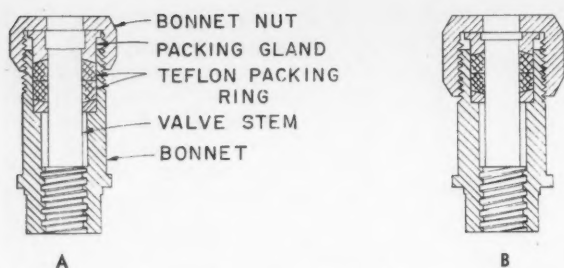


Figure 8—Details of bonnet assembly on 1-inch type cylinder valves. A—Present design. B—Modification proposed to minimize stress-corrosion failure in the bonnet and bonnet nut.

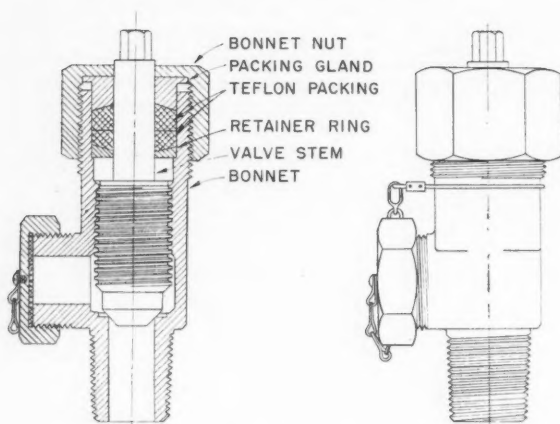


Figure 9—One-inch, 1-piece cylinder valve.

would be some stress in the bonnet (i.e., due to torque on the bonnet nut) below which the bonnet would not be susceptible to stress corrosion cracking.

A series of accelerated stress corrosion tests was conducted in mercurous nitrate solution on the cylinder valves to evaluate the effect of torque on the bonnet nut and the possible value of modifying the packing and bonnet nut locations to protect or reinforce the bonnet (Table 1). When no modifications were made on the locations of the bonnet nut and packing relative to the bonnet, the bonnet cracked during test when as little as 20 foot-pounds torque was applied to the bonnet nut (Tests 5, 6 and 7); cracking occurred very rapidly at a torque of 40 foot-pounds (Test 8). The arrangement of the bonnet assembly was then manipulated by cutting down the height of the top packing retainer so that the bonnet nut engaged nearly all of the threads on the bonnet. Although this resulted in the bonnet nut partly overlapping that area of the bonnet which was in contact with the packing, the bonnet still cracked in test because it was not fully protected from tensile stresses (Tests 13 and 14).

Additional modification was made by cutting down the thickness of the top packing retainer so that the bonnet nut engaged nearly all of the threads on the bonnet and by raising the packing entirely within the bonnet nut by using a thicker retainer under the lower packing. This modification appeared to be

effective in reducing susceptibility to stress corrosion cracking, because the bonnet did not fail at torque loadings on the bonnet nut as high as 80 foot-pounds (Tests 15, 16, 17, 18 and 19). However, it should be noted, from Test 19 at 80 foot-pounds torque, that the bonnet nut was now the more highly stressed member. Several other tests indicated that the bonnet nut was only slightly more resistant to failure than had been the bonnet on valves that were not modified (this verified by Test 8). Hence, it was indicated that the thickness of the bonnet nut also should be increased because the minimum thickness (root of thread to outer surface) of the nuts was only about 0.065-inch.

### Torque Considerations

In spite of these corrective measures, the stresses developed in the bonnets by the torque applied to the bonnet nut will determine whether or not a bonnet will fail by stress corrosion cracking. The magnitude of torque that should be applied to bonnet nuts must of necessity represent a compromise situation. On the one hand, the torque loading should be kept at the lowest possible value in order to keep the internal stresses at a low level in the bonnet. On the other hand, a minimum torque is required to obtain leak tightness. Because the valves are subjected to a number of thermal cycles during service, the torque applied to the bonnet must be sufficient to maintain leak tightness under these conditions of service life as well as during the first leak test of the new valve.

Cyclic heating and cooling tests on valves showed that the effective torque on the bonnet nut increases during the heating cycle and decreases after cooling. This is caused by thermal expansion and plastic flow of the Teflon packing. These changes in torque during heating and cooling in service should be taken into account in assembling the valves, to avoid either the development of excessive stresses during heating because of too high initial torque or the possibility of leaks during cooling resulting from too low initial torque. The test results indicated that torque on the bonnet nut in the range of 20-30 foot-pounds was about optimum with Teflon packing on these valves.

### Steps Taken to Minimize Bonnet Failures

Based on the results of this investigation, the bonnets were heat treated according to the treatment described above. In addition, the torque applied to the bonnet nut was fixed at 30 foot-pounds. Since these improvements have been incorporated, no bonnet failures have occurred with the existing valves.

Design modifications found desirable in order to further minimize the possibility of stress corrosion failures have been incorporated in a new design (Figure 9) for cylinder valves for future applications.

This document is based on work performed for the Atomic Energy Commission by Union Carbide and Carbon Corporation, K-25 Plant, at Oak Ridge, Tennessee.

# Corrosion Evaluation of Ship Bulkhead and Hull Plating by Audigage Thickness Measurements\*

By DWIGHT J. EVANS

## Introduction

**M**ETAL PLATE deterioration resulting from corrosion has reached serious proportions in many Type T-2 Tankers built during the war years and in other older vessels. Consequently, ship owners and the various regulatory bodies are concerned as to the condition of the vessels and extensive thickness measurements of internal bulkhead and hull plates are in order. Regulatory bodies, such as the American Bureau of Shipping and the U. S. Coast Guard, required periodic measurement of plate thickness, the time limit being governed by the type and variety of cargoes carried and frequency of tank cleaning. Although the corrosion rate in other types of ships usually is much less than that in tankers, periodic thickness measurements also are required for these vessels.

For many years, corrosion losses and rate of corrosion were determined by means of drilling holes, calipering and re-welding. Obviously, a ship must be in drydock in order to drill the hull plates and re-welded areas often are the focus of accelerated corrosion. The process is expensive and limits the number of thickness readings that can be taken, but was the only practical method available until the development of a non-destructive thickness measurement instrument, known as the Audigage. Use of the Audigage has reduced the cost of obtaining measurements to about 25 to 30 percent of those of the older method and results obtained by competent personnel are generally more accurate. The above represents a direct cost reduction. It does not include additional costs usually associated with drilling, such as drydock charges necessary when drilling bottom plates, testing cargo tanks for leaks after re-welding, income lost during the added time the vessel is out of service, etc.

The Audigage utilizes high frequency sound waves to measure steel plate thickness when applied to one side of the metal only.<sup>1,2</sup> The American Bureau of Shipping has accepted measurements obtained with the Audigage, provided the local American Bureau of Shipping surveyor approves the engineer conducting the tests, is convinced of his ability and integrity and in some cases, has checked a few of the Audigage readings with a micrometer. Figure 1 shows Audigage measurements underway on hull plates of a ship.

Ships are especially adaptable to the type of services offered by a specialized organization providing non-destructive thickness testing services. Testing them is a difficult application because of scale, corroded surfaces, accessibility, etc. and considerable skill and knowledge of the instrument is required. Furthermore, because ships may be repaired at any one of a

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large number of ports transportation of a test engineer and equipment usually is necessary in any case. Therefore, transportation cost is not a determining factor in the owners' decision to use testing services. A specialist can complete the tests in a fraction of the time required for relatively inexperienced operator, whose data often are useless and in several cases have proved actually to have been harmful. A spe-

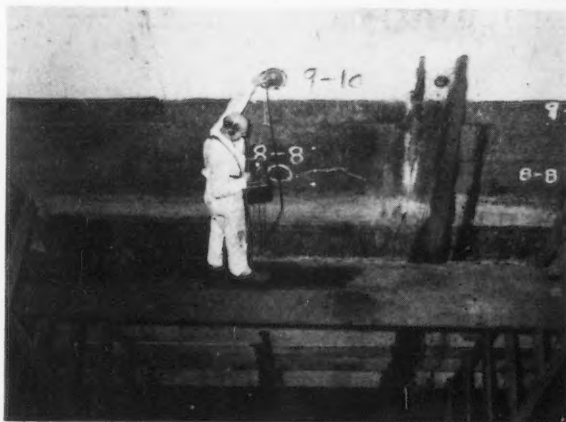


Figure 1

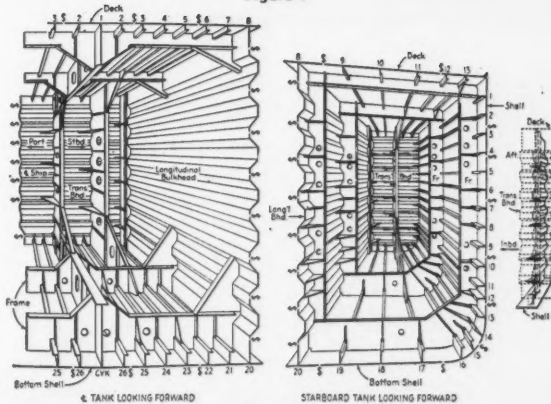


Figure 2

\*A paper presented at the Tenth Annual Conference, National Association of Corrosion Engineers, Kansas City, Mo., March 15-19, 1954 under the title "Nondestructive Thickness Measurement in the Marine Industry."

**TABLE 1—Plate Thickness of Typical Transverse Cargo Tank Bulkheads Port, Center and Starboard Tanks**

Transverse Bulkhead Plate	Thickness of Construction	After Trans. BHD. No. 2 Tank					
		PORT		CENTER		STBD.	
		Audigage Resonances	Thickness	Audigage Resonances	Thickness	Audigage Resonances	Thickness
Top Plate.....	.461"	1.82 1.47 P	.319"	1.83* 1.22 1.52 M	.380"	1.90 1.11 1.53 P	.306"
1st Strake.....	.461"	1.73 1.38 P	.337"	1.95 1.31 1.63 M	.356"	1.80 1.07 1.44 P	.322"
2nd Strake.....	.380"	1.79 0.90 1.33 M	.261"	1.99 1.20 1.60 G	.290"	1.80 0.91 1.35 G	.258"
3rd Strake.....	.420"	1.84 1.12 1.48 M	.314"	1.71 1.03 1.36 G	.339"	1.82 1.10 1.46 G	.319"
4th Strake.....	.440"	2.00 1.34 1.67 G	.347"	1.83 1.22 1.53 G	.381"	1.93 1.30 1.61 G	.360"
5th Strake.....	.461"	1.85 1.24 1.54 G	.375"	1.76 1.18 1.47 G	.395"	1.83 1.22 1.52 M	.382"
6th Strake.....	.500"	1.95 1.41 1.68 G	.414"	1.85 1.33 1.59 1.96 G	.440"	1.91 1.37 1.63 P	.410"
7th Strake.....	.520"	1.80 1.31 1.55 G	.451"	1.93 1.46 1.70 1.22 G	.477"	1.77 1.26 1.52 M	.458"
Bottom Plate..	.540"	2.00 1.50 1.75 1.25 G	.464"	1.92 1.45 1.69 1.21 G	.481"	1.78 1.27 1.53 G	.456"

NOTE: Audigage resonances designated as follows:  
 P—Poor Signal. M—Medium Signal. G—Good Signal.

**TABLE 2—Plate Thickness of Typical Longitudinal Bulkheads Port and Starboard Tanks**

Longitudinal Bulkhead Plates	Thickness of Construction	Cargo Tank No. 2 Longitudinal Bulkhead			
		PORT		STBD.	
		Audigage Resonances	Audigage Thickness	Audigage Resonances	Audigage Thickness
Top Plate.....	.500"	1.95 1.32 1.64 G	.352"	1.88 1.26 1.57 P	.371"
1st Strake.....	.500"	1.87 1.57 P	.371"	1.91 1.28 1.60 M	.362"
2nd Strake.....	.419"	1.73 1.04 1.39 G	.334"	1.77 1.07 1.43 G	.327"
3rd Strake.....	.419"	1.77 1.06 1.42 M	.327"	1.70 1.02 1.36 G	.341"
4th Strake.....	.441"	1.80 1.12 1.46 P	.332*?"	1.97 1.32 1.65 G	.353"
5th Strake.....	.480"	1.83 1.23 1.53 P	.381"	1.85 1.24 1.54 G	.376"
6th Strake.....	.539"	1.75 1.25 1.55 M	.464"	1.77 1.27 1.52 M	.458"
7th Strake.....	.580"	1.77 1.33 1.55 P	.522"	1.93 1.51 1.72 M	.540"
Bottom Plate.....	.620"	1.83 1.44 1.63 1.24	.572"	1.86 1.47 1.67 1.26 M	.557"

NOTE: Audigage resonances designated as follows:  
 P—Poor Signal. M—Medium Signal. G—Good Signal.

\* Indicates poor check of resonances with slide rule. Accuracy  $\pm .015$ ".

cialized organization necessarily must provide an unbiased analysis, if it expects to remain in business.

### Marine Corrosion and Its Control

The corrosion rate of internal and external cargo tank surfaces in sea-going tankers, with which this company is most familiar, is, as mentioned previously, variable with type and variety of cargo carried, frequency of tank cleaning, etc., but an average figure as determined by Audigage readings and tests by others,<sup>3,4</sup> is usually a loss on the order of .010-inch per year of service (average of penetration from both sides). This rate indicates that complete renewal of internal structures and partial renewal of external

structures, will be necessary during the anticipated 20 year life of the ship.<sup>3</sup> Minimum cost of such renewals is on the order of \$750,000, so there is a definite need for a rapid and inexpensive means of determining plate thickness at frequent intervals as well as for some means of mitigating the corrosion. Incidentally, it is interesting to note that in 1952 all Type T-2 Oil Tankers classed with the American Bureau of Shipping were required to be strengthened structurally by the addition of beams and/or reinforcing straps to provide a 15 percent increase in section modulus calculations.

Figure 2 is an isometric view of the interior of a Type T-2 cargo tank and Tables 1 and 2 illustrate typical Audigage thickness data obtained on the nine plates of typical transverse and longitudinal bulkheads. The data sheets show the original thickness, Audigage "resonance frequencies," and present thickness calculated from the resonances. As will be discussed later, the resonance frequencies are recorded because of their importance in obtaining accurate results. The letters "P," "M," and "G" following the resonances designate "Poor," "Medium" and "Good" signals and are an aid providing a qualitative analysis of the degree of pitting, as will be described.

A number of shipping companies operating oil tankers have instigated various corrosion control methods, such as magnesium anodes or chemical spray systems, particularly for internal bulkhead and structural members. Experiments with various types of chemical sprays, etc., were evaluated by test coupons or plates.<sup>5</sup> Complete installations were begun in 1950 and

with the application of fullscale corrosion control it no longer was practical or necessary to record actual progress by test coupon measurements. It was recognized, however, that experience records would be required to evaluate the systems. Subsequently, it was decided to use the Audigage at annual overhaul periods and the surveys were begun in June, 1950.<sup>3</sup> Several shipping companies are actively engaged in these corrosion control projects and annual Audigage testing provides rapid and practical means for their evaluation. Insofar as the writer knows, all evaluation of corrosion control work on actual ship plates in service is being done with the Audigage.



## Audigage Equipment

### Theory of Operation

The Audigage provides a means of measuring metal thickness when applied to one surface of a steel plate or other metals. High frequency sound waves projected into the plate from one side, are utilized in obtaining this measurement.

This instrument consists essentially of a high-frequency electronic oscillator, a quartz crystal "transducer" to convert electrical energy from the oscillator into the mechanical sound (pressure) waves and vice-versa and a means of measuring elapsed time. The sound waves (termed "ultrasonic" or "ultrasound" because the frequency is above the audible range) are beamed into the material from one surface by the transducer crystal, travel through the material at a constant velocity, are reflected at the opposite surface and returned to the transducer. Since velocity through a given material is constant, the time required for a wave to make the round trip is a function of the distance traversed, which in this case is equal to twice the thickness. Therefore, if a means of measuring elapsed time is available, the thickness can be determined. The time interval between successive recurrences of an oscillating frequency is a measure of time and in this instrument, the rate of oscillation (or frequency) is utilized as a timing device.

In actual operation, the frequency is adjusted to a point at which a wave is propagated from the transducer at exactly the same instant that the previously transmitted wave has arrived back at the transducer and a wave interference or "resonance" condition is set up, indicating that the first wave has traveled a distance equivalent to twice the thickness. This resonance condition is detected by the increased power required to drive the oscillator at that point. The resonance frequency is recorded and thickness calculated by taking one-half the product of the velocity constant and reciprocal of the frequency (elapsed time) at which resonance occurs (time =

$\frac{1}{\text{frequency}}$ ). It is also possible to have multiples of this wave in the material under test, the number being dependent upon the thickness and frequency range covered by the oscillator. In this case, the difference between any two adjacent frequencies (known as harmonics) is equal to the basic or fundamental frequency. The thickness, frequency and velocity relationship can be expressed as follows:

$$t = \frac{V}{2 \times (f_n - f_{n-1})} \quad (1)$$

Where:

- t = thickness
- V = velocity of the ultrasonic wave in the material under test (approximately 232000 inch per second in steel)
- $f_n$  = frequency at the nth harmonic in cycles per second.
- $f_{n-1}$  = frequency at the (n-1)th harmonic cycles per second.

### Characteristics

Since amplitude of vibration of the quartz crystal is microscopic, it must be in intimate contact with the

metal surface to which it is applied. A coupling medium between the quartz and steel plate, such as oil or glycerine, must be used to fill any surface cavities, etc. The waves cannot be transmitted through scale (except a tight "mill scale") and only very rarely through paint. Therefore, the metal surface to which the crystal is applied at the test location must be completely scaled and any roughness at least partially removed by a "disk sander," file, or emery cloth. In general, about one-half of the surface under the 1 3/8-inch diameter crystal must be clean, bright and "flat."

Thickness readings are not appreciably affected by deposits such as coke or scale, water, or other mediums on the side of the plate opposite the transducer, although signal strength will be reduced when such conditions are encountered and in extreme cases accuracy is reduced because of difficulty in determining the center of the resonance band. The thickness of the deposit is immaterial, because the interface between steel and scale, etc. is the determining factor. Under these conditions, a portion of the sound waves are reflected and a portion refracted at interfacial surfaces separating two materials that have different acoustical impedances (product of velocity and density), such as steel and water, or steel and scale. The ratio of reflected energy to incident energy and therefore, signal strength, is proportional to the difference in acoustical impedance, as shown in the following:

$$R_E = \left[ \frac{P_1 V_1 - P_2 V_2}{P_1 V_1 + P_2 V_2} \right]^2 \quad (2)$$

Where:

- $R_E$  = ratio of reflected to incident energy.
- $P_1$  = density of first medium.
- $V_1$  = velocity of sound in the first medium.
- $P_2$  = density of second medium.
- $V_2$  = velocity of sound in the second medium.

Signal strength is reduced and the resonance band broadened when the reflecting surface opposite the crystal search unit or transducer is rough and pitted, since there is an exact resonance frequency applicable to each different thickness under the standard 1 3/8-inch transducer diameter. A skilled operator is able to select the approximate center of this resonance band and, therefore, an average thickness approximately midway between the "peaks and valleys" is obtained. A qualitative analysis as to the condition of the unseen reflecting surface can be obtained if other factors, such as scale, are comparable. For example, a small patch of pits about 1/32-inch deep and 1/32-inch in diameter opposite the transducer and covering an area of about 1 square inch or greater will be detected by a skilled operator and classified as "slightly pitted." All resonance signals are classified as Good, Medium or Poor, on the data sheets, as shown in Tables 1 and 2. The "Good" signal indicates a uniform opposite surface, the "Medium" usually a slightly pitted surface, such as above, and "Poor" a badly corroded surface.

In addition to the effect that rough and pitted surfaces have in the reduction of signal strength, it is also possible to reach a point at which thickness variation under the 1 3/8-inch crystal diameter is so

TABLE 3  
Comparison of Typical Audigage Thickness Readings  
After Transverse Bulkhead, #2 Port

Transverse Bulkhead Plate	THICKNESS IN INCHES			
	Original	December, 1953	August, 1954	Reduction 1953 to 1954
Top Plate.....	.461	.319	.312	— .007
1st Strake.....	.461	.337	.328	— .009
2nd Strake.....	.380	.261	.252	— .009
3rd Strake.....	.420	.314	.308	— .006
4th Strake.....	.440	.347	.341	— .006
5th Strake.....	.461	.375	.372	— .003
6th Strake.....	.500	.414	.412	— .002
7th Strake.....	.520	.451	.443	— .008
Bottom Plate.....	.540	.464	.455	— .009

great that no signals can be obtained. In general, when the "peak-to-valley" depth of pitting exceeds 20 percent of the total thickness, or if it exceeds one-half wave length (approximately  $\frac{1}{8}$ -inch in steel at one megacycle), it will be impossible to measure thickness. This condition normally is not encountered in bulkhead and deck plating measurements but sometimes is present on hull plates. If it is encountered, a transducer movement of one or two inches is usually sufficient to obtain readings and depth of adjacent pits estimated or measured with a "pit depth" gage.

#### Accuracy

When the instrument is used by competent, trained personnel and a slide rule is utilized to check resonance points and calculate thickness, accuracies on the order of plus or minus one percent are obtained under average conditions. Average conditions include scale or water on the opposite side. On smooth surfaces, accuracies of about  $\frac{1}{2}$  percent are obtained. In the case of tightly adhering deposit with an acoustic impedance close to that of steel, such as is occasionally encountered with carbon deposits, accuracy is reduced to perhaps plus or minus three percent. These accuracies apply over a thickness range of from .060-inch to a maximum of several inches. It should be emphasized again, however, that such accuracy can be obtained only by a skilled operator.

Briefly, the slide rule checking procedure mentioned above consists of using a slide rule to adjust frequency difference  $f_n - f_{n-1}$  as shown in equation (1), to a value that is more accurate than is obtainable directly and at the same time obtain positive proof that the resonance signals, as recorded, are authentic. From the theory of operation, it is known that the resonance frequencies are exact multiples of the fundamental frequency, or difference between adjacent harmonics,  $f_n$  and  $f_{n-1}$ . Therefore, the resonance frequencies obtained in the tests can be divided by  $n$ ,  $n-1$ , etc. to obtain an accurate difference and consequent accurate thickness. Further, if each of the resonances obtained cannot be divided by successive harmonic numbers and an equal fundamental frequency obtained, the resonance is considered false or spurious and the resulting thickness reading questioned. For example, in Table 2, one reading is questioned for this reason.

The average thickness between "peaks and valleys" of a generally corroded plate usually is measured to an accuracy of approximately plus or minus 1 to 2 percent. The ability of the instrument operator to

select the central point of the broad resonance peak obtained when material is pitted or corroded on the opposite side is a determining factor in this case. It should be remembered that on a generally corroded plate such as is encountered in oil tank ships, thickness differences of perhaps .015-inch or more between "peaks and valleys" may be obtained within a  $\frac{1}{2}$  square inch area. It is interesting to note that thickness reductions on the order of a few thousandths of an inch per year are being measured under these conditions, as shown in Table 3.

As outlined previously, in order to insure satisfactory operation of the Audigage, it is necessary to prepare the surface of the plate to which the Audigage transducer unit is applied. In order to obtain an accurate analysis of normally corroded plate thickness, an effort is made to remove one-half of the maximum difference between "peaks and valleys" on the surface by means of emery cloth or a portable "disk sander" usually about .004-inch is removed. Such metal removal is usually done by laborers and must be closely supervised.

#### Techniques Developed for Audigage Surveys

An average Audigage survey of a T-2 Tanker specifies approximately 550 thickness readings on hull and bulkhead plates. In some cases, readings also are obtained on various structural members of the ship, either with the Audigage or a micrometer. A hull and bulkhead plate survey includes one reading on each plate in the bulkheads dividing the ship into various cargo tanks, approximately 100 thickness readings on strategic shell plates, usually in the forward, central and after sections of the ship and about 100 thickness readings on deck plates.

On T-2's there are nine plates welded together to form the vertical bulkheads, as shown in Figure 2, and distance from the top plate immediately below the deck to the plate at the bottom of the bulkhead is about forty feet. It is, therefore, necessary to provide a means of access to the upper plates. In order to expedite taking measurements, and to eliminate the necessity of scaffolding, etc., various techniques have been developed for obtaining thickness readings rapidly.

A so-called "basket and hoist" system has been developed specifically for Audigage surveys. In this method, a hole is drilled in the top deck adjacent to two bulkheads, the cable from the hoist is lowered through the hole and a basket attached at the bottom of the cargo tank. This access hole is later re-welded. Of course, these holes are detrimental, but since they are easily accessible for drilling and re-welding and one hole provides an inexpensive means of access for 18 Audigage readings in most cases, the net result is not considered serious. Also, they are an advantage in relocating test locations if so desired, when surveys are repeated each year. Seventeen of the 26 tanks on a T-2 Tank Ship require these holes. All other plates in the remaining nine tanks are accessible from permanent structures. Usually four units of this equipment are used and are employed first by shipyard laborers for cleaning the test locations to which the

transducer cleaned, bulkhead data sheet thickness readings and test one day.

When an adjustment of rope below the raised on the ship below the inside of plates about often by folding of as done.

In some thickness therefore from bracket readings labor is making "hoist" Principal having the cannot be.

1. The provides number of vessel at obtaining intervals reduced. ings obtained their accuracy.

2. The tion correct of the large neers are order of p measurement per year.

3. Because and valleys, corroded plate, this method of weight such results transducer which the "peaks and valleys".

4. When opposite thicknesses will be is greater During the

transducer is later applied. After the locations are cleaned, the test engineer or engineers, measure all bulkhead plates in each tank consecutively. An assistant records the Audigage resonance readings on the data sheets and no attempt is made to calculate thickness at the time. The approximately 550 readings are usually obtained by Engineering Test Services test engineers in about five man-days and about one day is required for checking and calculations.

When the "baskets and hoists" are not available, an adjustable scaffolding is sometimes used. Two sets of rope blocks are attached to beams immediately below the deck, a plank is attached and the operator is raised or lowered along the bulkhead. Hull plates of the ship are tested in various ways. Bottom plates below the waterline usually are measured from the inside of the ship, in the cargo tanks. Access to side plates above the waterline is obtained in various ways, often by boat or barge alongside, by a hoist or scaffolding on the outside, or from inside the cargo tanks, as done for the bulkhead tests.

In some cases, the ship owner may decide that thickness readings are not essential on all plates, and therefore, readings are taken only on plates accessible from brackets, "reach rods," ladders, or other permanent structures. In this procedure cost of obtaining readings is kept at a minimum, because shipyard labor is not required for building scaffolding, operating "hoists and baskets" or other means of access. Principal disadvantage of this system is that plates having the highest corrosion rate (top plates) usually cannot be reached.

### Conclusions

1. The Audigage, when used by a trained operator, provides a practical field method of obtaining a large number of thickness readings on a tank ship or other vessel at a comparatively low cost. Therefore, cost of obtaining the plate thickness required at specific intervals by the regulatory agencies is considerably reduced. The above agencies will only accept readings obtained by trained operators who have proved their accuracy.

2. The equipment is particularly useful in evaluation corrosion control systems now installed by some of the large shipping companies. Experienced engineers are consistently obtaining accuracies on the order of plus or minus 1 percent, making possible the measurement of corrosion rates of about .005-inch per year.

3. Because an average thickness between "peaks and valleys" on the opposite side of uniformly corroded plate is obtained by competent, trained personnel this method is comparable in accuracy to the "loss of weight" method of evaluation test coupons. For such results to be reliable the surface to which the transducer is applied must be ground to a point at which the surface is midway between the former "peaks and valleys."

4. When pitting is extremely severe on the surface opposite the 1 3/8-inch transducer diameter, no readings will be obtained. This occurs when depth of pits is greater than about 20 percent of plate thickness. During tank ship surveys conducted in the past

pitting of this severity is occasionally encountered in the hull plating. When this happens the only report possible is a "deep pitting" classification at that particular test location. In most cases, however, the transducer can be moved several inches and a satisfactory reading obtained.

5. Classification of Audigage signal strength and width of resonance bands enables the operator to qualitatively analyze the condition of the opposite surface as to degree of pitting, provided that other variables such as presence of scale and transducer contact remain relatively uniform.

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### DISCUSSION

Discussion by L. P. Sudrabin, 30 Main St., Belleville, N. J.:

In making measurement of a piling section below the water surface it must be necessary to condition the surface of the pile. How is this done? What is the range of accuracy attained in the observations made in underwater probing?

It is observed that corrosion of tankers in sour crude service is of a highly localized nature (pitting). The Audigage is useful in measuring metal thickness at the plateaus. This provides a baseline for evaluating the effectiveness of protection measures in controlling the pitting. Comparison is made of the pit depths and/or area plaster casts over intervals of time.

Reply by Dwight J. Evans:

You are correct in that surfaces of the piling must be prepared for testing even though the piling is submerged.

Accuracy attained in underwater testing is comparable to that obtained in conventional testing. It should be within plus or minus 3 percent and if the slide rule technique is used, within plus or minus 1 1/2 percent. Practically speaking, the only factor affecting accuracy of the Audigage, provided that signals are reasonably good, is a shift in actual frequency from that indicated on the tuning dial. A shift of three divisions (.03 mc.) will result in an error of about 1 percent. If the instrument is calibrated to the proper frequency with the long cable, accuracy under water is unchanged, since the fact that the cable and crystal are immersed in water has no appreciable effect on frequency. In this regard, it should be remembered that the quartz crystal in the Audigage does not control frequency as in the case of radio transmitters, but rather is used as a transducer of electrical to mechanical energy and vice-versa. There-

\* Note: This discussion originated from a statement in the original paper regarding underwater testing. The statement is not made in this paper.



fore, temperature changes of the crystal, etc., has no appreciable affect on frequency generated in the Audigage. Of course, the cable, crystal and joints were thoroughly water-proofed, because the instrument would be inoperative if 100 percent water-proofing is not obtained.

In regard to highly localized corrosion (pitting) in tankers, it is agreed that the instrument is useful in measuring metal thickness at adjacent plateaus. The pit depth then can be measured by a "pit depth gage" and the thickness of the remaining metal calculated. In the writer's experience (usually tankers in gasoline service), most of the deep isolated pits observed have been in the bottom hull plates of the ship, on the inside surface. In one recent test, the writer was able to measure the thickness from the plateau adjacent to the pit, measure the pit depth and thus calculate thickness of the remaining metal. The pit in question was a fairly large diameter, approximately  $\frac{3}{4}$ -inch at the bottom and the writer was also able to use a special small Audigage crystal  $\frac{3}{4}$ -inch in diameter in the bottom of the pit. Thickness of the remaining metal obtained correlated with that calculated.

**Question by H. O. Teeple, International Nickel Co., Inc., New York:**

Do you relocate accurately points of thickness measurement for subsequent surveys?

**Reply by Dwight J. Evans:**

In some cases the points for subsequent thickness measurements are relocated accurately for each test. In other cases, readings are taken in the general area, usually within about one foot of the previous readings. It is the writer's present opinion that relocation accurately is not necessary, or particularly desirable on bulkhead plates which corrode on both sides, but is desirable on the heavier deck and shell plating in which one side is protected from corrosion and in which there usually is considerable variation in original thickness due to "camber" effect in rolling. The variation in original thickness of the heavier deck and shell plates often is greater than the corrosion loss and therefore, care should be used in accurate relocation. Bulkhead plates are in the range of .250 to .550-inch, and shell and deck plating .750 to 1.250-inch.

As stated in the paper, the Audigage in the hands of a skilled operator will provide an average of the thickness between "peaks and valleys" on the opposite surface. If the corrosion is uniform, as is usually the case on the internal bulkheads, then theoretically Audigage readings would be identical throughout a given area of a given plate, if original thickness is uniform. In the writer's experience, this is never quite true, but surprisingly, it often is found that variation between a test spot 1-inch from the original and one 10 feet from the original is comparable. This, of course, is true only when original thickness throughout the plate is comparable, as is usually the case with internal bulkhead plates. Results obtained in two different locations on a number of bulkhead plates shown in Table 1 herewith.

Another factor to be considered in using identical locations in each survey is the fact that some metal

**TABLE 1**  
**Comparison of Longitudinal Bulkhead Thickness**  
Center of tank and after end (Approximately 15 feet between locations).  
All readings on the second plate down from top deck.

Tank No.	Audigage Thickness at Center-Inches	Audigage Thickness After End-Inches
2 Starboard.....	.403	.380
3 Starboard.....	.378*	.398
4 Starboard.....	.368*	.394
5 Port.....	.332*	.396
6 Port.....	.324*	.368
6 Starboard.....	.351	.357
7 Port.....	.403	.398
7 Starboard.....	.408	.419
8 Port.....	.362	.378
9 Port.....	.427	.421

\* These duplicate readings were taken because a somewhat greater corrosion rate in the center of the tanks was suspected, particularly tanks No. 3, 4, 5 and 6, as shown\*.

will be ground off in preparing the test spots. This is inevitable, because, as stated above, both sides of the plate are corroded and the surface prepared for the previous reading must be re-cleaned. In cleaning or grinding test spots, a "disc sander" is used and an attempt is made to remove about one-half of the "peaks," thereby providing a test surface which is an average between "peaks and valleys." Frequently more metal is removed than is necessary, particularly if the cleaning is done by plant laborers.

The writer has a project under way for a customer in which during the first survey one reading on each plate was taken. This location was marked accurately and each reading is to be repeated this year. In addition, a reading is to be taken about one foot from the original area. Present plans are to repeat this process for several years. Each year, all of the previous readings are to be relocated accurately and a new reading added. Conclusive data is expected when these tests are completed.

The writer would like to emphasize that the problem of measuring thickness of internal tanker bulkheads is considerably different than that normally encountered in pressure vessels or other plant equipment, in which one surface remains protected by paint, insulation, etc., particularly if readings are taken from the inside and the protected side is the reflecting surface. In such cases, accurate relocation is vital if high accuracy is desired, unless the side from which readings are taken is uniformly corroded and it is necessary to grind a surface for testing.

During the past four years, the writer's firm has made annual surveys on four ships, in connection with a corrosion control program. No attempt was made to relocate readings exactly and evaluation is based on averages of readings on comparable plates in each tank, etc. Gross inconsistencies have been found in the heavier deck and hull plate readings (when one side is uncorroded and protected), but the over all average of thickness readings on internal bulkheads has shown a consistent corrosion rate and the writer is measuring changes in average thickness on the order of .005-.015-inch. These data undoubtedly will be released when the project is completed.

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# Metallizing for Corrosion Prevention\*

By A. P. SHEPARD and R. J. McWATERS\*

THERE ARE MANY methods of coating iron and steel with other metals to prevent corrosion. One method is by metallizing, the subject of this paper. The word "metallizing" as used herein means, "The spraying of molten metal." A metallizing machine will spray any metal that can be obtained in wire form. However, this discussion pertains only to the application of pure zinc and aluminum with various after treatments.

Surfaces to be coated with these metals must be thoroughly cleaned and roughened to obtain the necessary bond. Except for a few special jobs, this preparation is accomplished by sand or grit blasting.

## Surface Preparation

Several types of abrasive may be used for the blast operation. The first requirement for this abrasive is that it be sharp and angular. On inside work where the abrasive can be reclaimed, angular steel grit or aluminum oxide is generally used. This material may be re-used from ten to one hundred times if kept free from contamination and excessive fines. The most commonly used material for inside work is crushed steel grit, size numbers SAE G-18 to G-40. The size will depend on the degree of roughness and bond strength required. Suction feed, force feed and centrifugal blast machines are used.

On outside work, where the abrasive cannot be recovered, sharp angular sand is used. This may be silica, flint, crushed quartz, crushed natural garnet, or crushed slag, with a mesh size of 12 to 50. Where desired, any sand may be used for a preliminary cleaning but the final blasting must be done with the specified materials.

The exact mesh size of the abrasive depends on the metal and thickness to be applied. For zinc or aluminum .005-inch thick, the finer size abrasives may be used (sand 30 to 50 mesh). For zinc .010-inch thick, a larger sand size is required (20 to 24 mesh). For aluminum .010-inch or thicker, the same 20 to 24 mesh sand is required plus an additional bonding coat.

## Bonding Coat Prevents Failure

The bonding coat is a flash coat of low carbon steel applied with a metallizing gun to a thickness of .001 to .002-inch. Bond strength will be approximately doubled by this procedure. It is required because coatings shrink and develop a tensile stress. Where thin coatings are applied this stress is negligible, but with heavier coatings it may produce a shear stress at the interface or bond line. Also, under certain conditions, corrosion products may be pro-

## Abstract

Problems and techniques connected with the spraying of molten metal on iron and steel to prevent corrosion are surveyed, including surface preparation, bonding coat, organic sealers and the relative merits of the various metals sprayed. Characteristics of zinc and aluminum coatings are discussed and recommendations are made for selection vs. environment anticipated. A list of recommendations for specific applications includes ship's hulls, oil tanker interiors, fresh water tanks, marine atmospheric exposures, railroad bridges, steel piling, industrial atmospheres, exhaust stacks and mufflers and river lock gates.

duced at this interface and cause blistering if bond strength is low. The use of the steel flash bonding coat prevents failure from shrinkage and blistering.

Actual bond strength in shear may vary from 2000 to 10,000 psi depending on the degree of preparation, thickness of coating and metal used. This strength provides an adequate margin of safety and, of course, is many times that obtained with organic coatings. The bond permits rough handling as the coating can be removed only by cutting away the metal. Consequently, coatings can be applied during shop fabrication leaving only joints and touch up work to be done in the field.

The metallizing operation should be done as soon as possible after the blasting is completed. Any contamination of the surface before spraying will cause blistering. The thickness of the coating depends upon the speed of traverse over the surface and the number of coats applied. In application, two, three, four or more coats are used to give the final thickness desired. The average thickness of one pass with zinc is .002-inch. A commonly used coating thickness is .005-inch and this would be applied in two or three passes. The spraying speed for coatings .005-inch thick will vary from 50 to 200 sq. ft. per hour, depending on the size and accessibility of the structure.

## Checking Coating Thickness

Coating thickness should be carefully checked after application with an approved magnetic thickness gage. Additional sprayed metal may be added where required, provided the surface has not been contaminated.

It is now customary in the metallizing industry to use organic sealers or top-coats with these metals. Many people ask, "If sprayed metal is so good, why do you have to seal it or paint it?" Here is the answer—"The combination of metallized zinc or aluminum with organic sealers provides the lowest yearly cost protection for most applications."

Sprayed metal is slightly porous and the surface is quite irregular. Every square inch of measured surface may have several square inches of zinc or aluminum exposed to the environment. A treatment

\*A paper presented under the title "Metallizing Economics in Modern Industry" at the Eighth Annual Conference, National Association of Corrosion Engineers, Galveston, Texas, March 10-14, 1952.

\*Metallizing Engineering Co., Inc., Westbury, N. Y.

which fills the pores and minute valleys in the surface has the effect of reducing the exposed area to a fraction of the original. The corrosion rate thus falls off proportionately. Because of its texture, sprayed metal catches and retains soot and other contamination. Consequently, where appearance is a factor, a sealer is essential to provide a relatively smooth surface which will stay clean.

### Requirements for Sealers

The principal requirements of paints or sealers to be used with sprayed metal are as follows:

1. The obvious requirement that they must be resistant to the environment. However, paints which might fail by crazing or loss of adhesion on other surfaces sometimes can be used over sprayed metal.
2. They must be chemically compatible with the sprayed metal. Some formulations which perform well on steel will fail rapidly on zinc or aluminum.
3. They must have good penetrating ability. Heavy, viscous paints may do more harm than good. Heavily pigmented paints should be avoided, except perhaps as a final coat following one or two coats of sparingly pigmented paint.

### Proper Sealers

When applying sealing or top-coats to zinc, strongly acidic wash prime treatments which may be suitable for hot-dipped zinc, should not be used for sprayed zinc. Straight oil bases, alkyd oil bases, and phenolic bases are not generally satisfactory. Recommendations of recognized contract shops should be taken with regard to the proper sealers. These will generally be special vinyls and chlorinated rubbers.

The fact that the organic materials must be compatible with the sprayed metal cannot be emphasized too strongly. There are far too many examples of failures because one concern applied the metallized coating and a second concern applied a paint coating on top of it that should not have been used. It would have been far better to leave the coatings bare.

The preparation and application of material have been discussed. One of the first considerations in preparing specifications for a job is which metal should be used—zinc or aluminum.

Here are the relative merits of each metal:

Metallized zinc coatings might be called spray galvanizing. Zinc wire with a minimum purity of 99.9 percent is used. A coating .003-inch thick provides one and one half ounces per square foot of surface and compares with the average galvanized coating. However, when needed coatings up to .020-inch may be applied. Zinc applied by hot-dipped galvanizing has a life roughly in proportion to its thickness. The same is true generally of heavy coatings of sprayed zinc or of properly sealed light coatings. Unless sealed, thin coats of sprayed zinc .001-inch to .003-inch may fail prematurely because of electrolysis which occurs at the voids.

Under conditions which result in the formation of dense, relatively insoluble salts in the pores of the zinc, sealing may not be necessary. Such a condition would exist in well aerated fresh water having a pH value of 8 to 9. Zinc is at its best in the pH range of 8 to 12, but under some conditions it may show good resistance in slightly acidic environments.

### Voids Will Be Protected

Because zinc is strongly anodic to steel, it will confer protection to relatively large voids. A broad scratch line through the coating will show some initial rusting at atmospheric exposure but as soon as sufficient rust has formed to retain some moisture, the adjacent zinc will function as an anode and prevent further rusting. In fresh water of average electrical resistance, zinc will protect steel at voids an inch or more wide. In sea water, the protection will extend several inches.

On outside structures having joints which are not readily accessible, zinc has considerable advantage over aluminum, because of the greater galvanic protection it affords. In a sense, sprayed zinc coatings often can be considered a form of cathodic protection. A fact that is often disregarded is that sprayed zinc will confer a measure of protection to other bare parts of the structure. While there may be some superficial rusting at adjacent areas, heavy attack and pitting often is prevented in the same way that zinc slabs on a ship hull prevent serious pitting at breaks in the paint. The coating will, of course, be depleted in proportion to the extent that it protects bare steel areas and if the ratio of bare area to coated area is large, the coating cannot be expected to last very long.

Aluminum has not been sprayed as widely as zinc for corrosion protection. A few of the reasons for this are:

1. Very little background is available on aluminum coatings whereas there is much data on zinc coatings applied by other methods.
2. Aluminum forms a protective oxide coating in water and industrial atmospheres which limits its capacity to confer galvanic protection to large voids.
3. Sprayed aluminum is subject to rust stains unless properly sealed.

It is true, nevertheless, that many jobs should be done with pure sprayed aluminum instead of zinc. Some of the reasons for using aluminum are:

1. Aluminum has much better resistance in an acid environment, and may be used in waters having a pH value as low as 2.5 to 3.
2. It has better resistance to sea water and salt atmosphere.
3. Where only a small percentage of the total area is to be coated, aluminum is preferable when the area is submerged. With a large unprotected area, zinc would fail rapidly because of the greater electrolytic action and the large cathode area. An example of this was encountered recently on the bulkheads of a tanker. The horizontal stiffeners and rivets were pitted and corroded to a degree where further attack would dangerously weaken the bulkheads. A band of sprayed aluminum covering the stiffeners and rivets was used because the aluminum will sacrifice itself very slowly in the electrolyte.
4. It has better resistance to industrial atmospheres. This is perhaps the greatest advantage.

The rust staining problem has been easily solved by simple, inexpensive sealing treatments. Clear vinyl and aluminum vinyl are used where seal coats only are required.

Sprayed aluminum, unlike sprayed zinc, is an excellent base for a wide variety of paints. The life of the

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paint itself may be doubled or tripled and even after the paint finally fails, complete corrosion protection remains. Further, the job of re-painting is not complicated by the necessity of removing rust and scale.

Sprayed aluminum is also used for heat-resistant applications. This includes both heat corrosion and weathering, for such service as exhaust stacks and mufflers, where the temperature may vary from normal outside temperature up to 900 F. For such work, the sealer is a silicon base vehicle containing aluminum pigment. This combination provides almost perfect protection and excellent appearance for many years.

For straight heat corrosion encountered in furnaces, the aluminum coating is alloyed to the steel by heat treating. This is a separate field which will not be discussed in this paper.

### Specific Applications

#### *Ship's Hulls*

Sprayed zinc has been used with some success as an anti-fouling coating for ship hulls. It is the only known system which resists fouling and at the same time protects the steel electrolytically. Based on the experience of a fairly large number of pleasure boats, fishing boats and barges, sprayed zinc will prevent fouling for a period of one to three seasons. After serious fouling has begun the coating will provide an excellent base for vinyl anti-fouling systems.

A user of the process had a problem with steel hull tugboats operating in the Delaware River. While there was no fouling problem, the corrosive conditions in the river resulted in early failure of conventional coatings. In this case, a coating of zinc .008-inch thick was applied, followed by two coats of a special chlorinated rubber. Subsequent inspection showed no attack on this combined coating and apparently the corrosion problem has been solved.

#### *Oil Tanker Interiors*

In June 1949 the interior of a forward tank on an oil tanker was coated with zinc. A flash bonding coating plus .008 in. of zinc was used. This tank carries acetone and under normal use corrodes very badly and causes discoloration of the product. On the last inspection, after three years in service, the coating was in perfect condition.

It is common practice on tuna clippers and other fishing craft with steel hulls to metallize the bait tanks, fish tanks, and exterior above the water line. Several hundred thousand square feet of surface on fishing craft have been metallized by one West Coast firm. On the exteriors, compatible primers and vinyl top-coats are applied and ships done in 1947 are still corrosion free where it was necessary previously to re-coat at least once a year.

#### *Fresh Water Tanks*

Interiors of fresh water storage tanks are given real protection from corrosion with metallized zinc. Tanks in Erie, Pennsylvania and in Buffalo have coatings that are intact after 17 years of service. There has been no loss of weight in the steel during

that period. It is the writer's opinion that coatings properly applied in accordance with present day specifications could protect interiors of cold water storage tanks for 30 years or more. Knowing this, designers could lighten such structures considerably.

#### *Salt Atmosphere*

An example of severe atmospheric corrosion was apparent on a wind tunnel located on the West Coast. The exterior was subject to a heavy salt atmosphere with some industrial fumes. When in use, it was cooled with water spray. And, of course, there was the usual action of wind, rain and sun. Paint coatings began to fail in less than one year and required re-application every two years. Zinc .010-inch thick was applied more than three years ago and the maintenance problem has been greatly reduced.

#### *Railroad Bridges*

On railroad bridges where the decks corrode badly from brine drip, metallized zinc has provided protection for periods up to 15 years. The proper use of sealers will lengthen this life.

#### *Steel Piling*

Steel piling presents a severe problem at and above the water line. Work has been done both on new piling and on existing structures. The coating will withstand the effect of driving. Sealers are used only above the water line. The life of existing structures can be lengthened considerably, if not doubled, with either zinc or aluminum. Zinc is considered preferable where it is necessary to do the work in place.

The Panama Canal issued a report on a Protective Coatings Investigation. The summary and conclusions appeared in the February, 1951 issue of Corrosion. Some of the conclusions were:

- a) The systems which show outstanding performance are those which have been zinc metallized.
- b) Zinc metallizing provides a sacrificial prime coat which acts as secondary protection if and when the organic top-coats have deteriorated or become damaged.

#### *Industrial Atmospheres*

A job completed recently in the middle west is typical of the use of aluminum in industrial atmospheres. A highway overpass near the railroad yards in Kansas City had all steel members protected with .008 inch aluminum, plus two coats of aluminum vinyl. This steel work, of course, is subject to smoke and Diesel engine exhaust as well as the usual weathering. A long lasting system is badly needed for this service and the pure aluminum should give the best protection.

#### *Exhaust Stacks and Mufflers*

Many gas pipe line companies have metallized exhaust stacks and mufflers. Where the recommended systems have been used, aluminum provides long protection. When a failure was reported on a small muffler recently, inspection showed considerable rust staining and some blistering. The reason

for the blistering was improper preparation. Either the abrasive was too fine or the surface was not blasted sufficiently. The rust staining resulted because no sealer coat was applied.

#### *River Lock Gates*

Lock gates on the Mississippi River were metallized with pure aluminum in February 1949. The last inspection in July 1951 revealed no apparent attack on the aluminum. Various seal coats also were tested and some had washed away to a considerable extent while others were still protecting the aluminum. This job was particularly difficult to do because of below zero weather during application.

The American Welding Society's Committee on Metallizing has started an extensive test program to determine thickness requirements and metals best suited for various conditions. Approximately 4400 test specimens have been exposed at various sites throughout the country. This should materially help industry in the years to come.

In the meantime, industry can help itself by using sprayed metal coatings wherever severe corrosion is

encountered. The cost of replacing steel structures has at least doubled during the last ten years.

So why not conserve present structures with coatings that assure long life without continual re-application? Corrosion engineers particularly, should be testing these coatings to determine their value under varying conditions.

#### DISCUSSION

**Question by Lawrence L. Whiteneck, Long Beach, Cal.:**

Is a primer designed for galvanized steel suitable for application on metallized coatings?

**Reply by A. P. Shepard:**

Not necessarily. Highly reactive types should be avoided, because such priming treatment attacks metallized zinc internally and weakens or degrades the coating. Primers heavily pigmented with zinc:zinc oxide are not suitable because the vehicle penetrates the sprayed metal and leaves a surface film having insufficient binder. Where the PVB type of primer is used, the phosphoric acid content should not be over 4 percent.

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# Corrosion of Aircraft Structural Materials By Agricultural Chemicals\*

## 2. Effect of Insecticides, Herbicides, Fungicides and Fertilizers

By CHARLES F. SCHREIBER\*

### Introduction

THIS INVESTIGATION covers a study of the corrosive effects of the generally used agricultural chemicals on the structural materials used in aircraft and dispersing equipment. It has been carried out to fill a need expressed by aerial applicators, aircraft manufacturers and agricultural chemical manufacturers.

Because a relatively small amount of corrosion work has been accomplished in the agricultural chemical field, a rather extensive testing program was felt necessary to include the many compounds in use today. In line with this program, a wide survey of the many aircraft structural materials and finishes were made. The testing program thus was designed to relate all the commonly used sprays, dusts, spray emulsions and fertilizers with the structural materials and finishes that are met in actual practice.

The aim of this project is ultimately to furnish the many crop dusting and spray operators definite information as to the resistance of a commonly used structural material or finish against the many agricultural chemicals.

As a general rule, most of the agricultural corrosion information now on hand was obtained through costly trial and error procedures in actual practice. This information was good and was used as a comparative measure in this work. It is hoped that this paper will include useful information that will save much of the trial and error cost of finished applications.

### Procedures Followed and Description of Apparatus

As a result of an extensive survey conducted on the many agricultural chemicals, the following compounds were used in this project:

**Insecticides**—Aldrin, Aramite, Arsenate dust, BHC, Chlordane, DDT dust, DDT plus solvent, Dieldrin, Heptachlor, Parathion, Sulfur, TEPP, Toxaphene, Toxaphene-sulfur dust.

**Herbicides**—Ammonium sulfamate, CMU, Potassium cyanate (high and low concentration), Sodium cyanamide, richloroacetate, 2,4-D plant stimulant, 2,4,5-T plant stimulant.

\*Submitted for publication October 27, 1954. The second of two papers under this heading. The first subtitled "1. Laboratory Tests With Fertilizer Compounds," was published beginning on Page 44 of the February, 1955 issue of Corrosion.

\*Dow Chemical Company, Freeport, Texas. Formerly with Personal Aircraft Research Center of Texas Engineering Experiment Station, Texas Agricultural and Mechanical College, College Station, Texas.

### Abstract

The corrosive and surface destruction effects of the generally used agricultural chemicals were tested on the structural materials and finishes used in agricultural aircraft and dispersing equipment. A total of 512 specimens of structural materials and finishes were tested partially submerged and 297 were tested under atmospheric conditions.

A thorough study was made of the agricultural chemicals that are now commonly applied by aircraft. New compounds that have a promising outlook in the crop dusting program also were included. The structural materials tested included the most frequently used metals, basic finishes, plastics and doped fabrics. Because there are more than 3000 protective coatings on the market, only the fundamental finishes could be included in this investigation.

As an overall summary of results it was found that only two materials tested, Type 302 stainless steel and polyester plastic reinforced with fiberglass, offered complete protection from all of the solutions investigated. Monel metal resisted corrosion reasonably well, but brass, aluminum alloy and chrome-molybdenum steel were all destroyed by certain of the agricultural chemicals.

A furan protective coating with a butyral primer demonstrated the best overall finish characteristics, although none of the applied finishes that were tested withstood all of the agricultural chemicals without damage.

TABLE A

#### Basic Paint Systems Tested for Corrosion Resistance

System 4 used in submerged tests only, System 5 used in atmospheric and submerged tests.

System No.	
1	<b>Prepolymerized Furan Finish</b> This finish consisted of one spray coat of a wash primer of the polyvinyl butyral group followed by two spray coats of a pre-polymerized furan coating with no plasticizer. Average thickness: 4.5 mils (0.0045 inch). Color: Gray. <sup>1</sup>
2	<b>Epoxy-Based Finish</b> This finish consists of one brush coat of an epoxy-actalyst primer and two spray coats of an epoxy-based finish. Average thickness: 5.5 mils (.0055 inch). Color: White. <sup>2</sup>
3	<b>Vinyl Plastic-Base Finish</b> The application of this finish was preceded by a 5 percent phosphoric acid 95 percent ethyl alcohol prewash. Following a flushing with clear water and air-drying, a flash spray coat of a chromate wash primer, was applied. This, in turn, was followed by spray coats of a synthetic resin pigmented with red lead and a vinyl resin base top coating. Thickness: 3 mils (.003 inch). <sup>3</sup>
4	<b>Modified Chlorinated Rubber Finish</b> A phosphate pre-coating was used prior to the application of this finish, which is used by Piper Aircraft Corporation. <sup>4</sup>
5	<b>Liquid Neoprene Finish</b> A recommended Neoprene primer coat was applied to the test samples followed by two brush coats of a liquid Neoprene coating which air dried to a live vulcanized rubber. Average thickness: 5.0 mils (.005 inch). (The manufacturer recommended this finish only for atmospheric and limited submerged conditions). <sup>5</sup>

(1) Manufactured by the Carboline Co., St. Louis under the trade names "B" Resin Primer and "B" Resin Gray (finish coating).

(2) Manufactured by the Carboline Co. under the trade names Primer No. 10 and Epoline 150.

(3) Manufactured by Minnesota Mining and Manufacturing Co., St. Paul, Minn. under the retail name of "Coro-Gard."

(4) Manufactured by Rexton Finishes, Inc., Irvington, N. J. under the trade name Rexadur SS.

(5) Manufactured by the Pennsylvania Salt Manufacturing Co., Philadelphia under the trade name Neocote.



TABLE 1

**Test Specimens:** 24S-T3 Alclad aluminum alloy with no applied finish.

**Test Conditions:** Tests conducted at room temperature under partial submergence.

Environment*	Time (Days)	Physical Change of Sample		Pertinent Observations During Test	Conclusions
		Vapor	Liquid		
1. Aldrin	75	No Change	No Change	Very slight pitting at 65 days; no metal damage	Excellent
2. Chlordane	75	No Change	No Change	Very slight pitting at extreme bottom of sample	Good
3. TEPP	75	No Change	White film	White protective film formed at 56 days; very slight pitting at 75 days	Good
4. Toxaphene	75	No Change	Slight Pitting	Slight pitting commenced at 65 days	Good
5. Aramite	75	No Change	Pitted area	Localized pitting at one submerged area at 56 days	Fair
6. BHC	75	No Change	Pitting	Very slight pitting at 70 days	Good
7. Potassium cyanate	75	No Change	No Change	Sample unaffected	Excellent
8. Potassium cyanate	75	No Change	No Change	Sample unaffected	Excellent
9. Sodium cyanamide	75	No Change	Rough	Active metal pitting commenced at 2 days; severe pitting at 14 days	Unacceptable
10. Magnesium chlorate	75	No Change	No Change	Very slight interfacial pitting	Acceptable
11. Magnesium chlorate	75	No Change	No Change	Very slight interfacial pitting at 60 days	Acceptable
12. TCA	14	Weak	Brittle	Metal action commenced at 2 days, severe at 6 days	Unacceptable
13. Liquid fertilizer	75	No Change	Interface pitting	Liquid level breakdown commenced at 56 days	Acceptable to 50 days
14. Liquid fertilizer	75	No Change	Interface pitting	Liquid level breakdown commenced at 56 days	Acceptable to 50 days
15. Ammonium sulfamate	75	No Change	No Change	Sample unaffected	Excellent
16. 2,4-D	75	No Change	Slight pitting interface	Pitting commenced at 60 days	Acceptable
17. Parathion	75	No Change	No Change	Sample unaffected	Excellent
18. 2,4,5-T	75	Pitted	Pitted	Pitting at interface commenced at 36 days; pitting at edges and in vapor phase at 60 days	Unacceptable over an extended time
19. Carbamate	75	No Change	No Change	Sample unaffected	Excellent
20. Carbamate	75	No Change	No Change	Sample unaffected	Excellent
21. Water	75	No Change	Pitted	Pitting commenced at 24 days; liquid level corrosion at 36 days, definite metal damage at 56 days	Acceptable for short periods
22. Kerosene	75	No Change	No Change	Sample unaffected	Excellent
23. Xylene/Kerosene	75	No Change	No Change	Sample unaffected	Excellent
24. DDT/Xylen Kerosene	75	No Change	No Change	Sample unaffected	Excellent
25. Aldrin + water	60	No Change	Pitting Interface	Pitting at interface commenced at 30 days	Acceptable for short periods
26. Dieldrin	60	No Change	Interface pitting	Pitting at interface at 30 days	Acceptable for short periods
27. Heptachlor	60	No Change	Interface pitting	Commenced pitting at 35 days	Acceptable for short periods
28. Ammonium Nitrate	60	No Change	No Change	Sample unaffected	Excellent

\* Refer to Table B for solution concentrations.

TABLE B

**Concentration Key for Atmospheric and Submerged Tests**  
Basis: Nominal 4 gallons per acre coverage.

1. Aldrin + xylene and kerosene solvent, concentration 0.0625 lb./gallon.<sup>1</sup>
2. Chlordane + water, concentration 0.25 lb./gallon.<sup>1</sup>
3. TEPP + water, concentration 3 percent.<sup>1</sup>
4. Toxaphene + kerosene solvent, concentration 0.375 lb./gallon.<sup>1</sup>
5. Aramite + water, concentration 0.25 lb./gallon.<sup>1</sup>
6. BHC (gamma isomer prominent) + xylene and kerosene solvent, concentration 0.0625 lb./gallon.<sup>1</sup>
7. Potassium Cyanate (low concentration) + water, concentration 2 percent.<sup>1</sup>
8. Potassium cyanate (high concentration) + water, concentration 4 percent.<sup>1</sup>
9. Sodium Cyanamide + water, concentration 4 percent.<sup>1</sup>
10. Magnesium Chlorate (low concentration) + water, concentration 0.1 lb./gallon.<sup>1</sup>
11. Magnesium Chlorate (high concentration) + water, concentration 0.4 lb./gallon.<sup>1</sup>
12. TCA (soluble sodium salt) + water, concentration 1.25 lb./gallon.<sup>1</sup>
13. Liquid Fertilizer (nitrogen 6 percent, phosphoric acid 25 percent, potash 15 percent) (low concentration) + water, concentration 0.06 lb./gallon.<sup>1</sup>
14. Liquid Fertilizer (nitrogen 6 percent, phosphoric acid 25 percent, potash 15 percent), (high concentration) + water, concentration 0.2 lb./gallon.<sup>1</sup>
15. Ammonium Sulfamate + water, concentration 0.75 lb./gallon.<sup>1</sup>
16. 2,4 D-Sodium salt + water, concentration 0.19 lb./gallon.<sup>1</sup>
17. Parathion (liquid) + water, concentration 0.5 percent.<sup>1</sup>
18. 2,4,5-T (liquid salt) + water, concentration 0.2 lb./gallon.<sup>1</sup>
19. Carbamates (low concentration) + zinc sulfate and water, concentration 0.5 percent.<sup>1</sup>
20. Carbamates (high concentration) + zinc sulfate and water, concentration 5.0 percent.<sup>1</sup>
21. Water—control in submersion and atmospheric tests.
22. Kerosene—control in submersion and atmospheric tests.
23. Xylene (xylene 10 percent, kerosene 90 percent) control in submersion and atmospheric tests.
24. DDT plus solvent (xylene and kerosene), concentration 0.1 lb./gallon.<sup>1</sup>
25. Dieldrin + water, concentration 0.0625 lb./gallon.<sup>2</sup>
26. Heptachlor + water, concentration 0.0625 lb./gallon.<sup>2</sup>
27. Ammonium Nitrate + water, concentration 10 percent.<sup>2</sup>

The following materials were applied as pastes in the atmospheric tests only:

28. Bordeaux Mixture.
29. DDT dust (gamma BHC 3 percent, DDT 5 percent, Sulfur 40 percent).
30. Toxaphene and sulfur dust, concentration 40 percent.
31. Sulfur.
32. Arsenates.
33. 8-8-8 commercial fertilizer.

TABLE 2

**Test Specimen:** 24S-T3 Alclad aluminum alloy with no applied finish.

**Test Conditions:** Specimens were exposed continuously to the atmosphere while being treated with the testing medium at three-day intervals.

**Note:** The following table is a summary of the environments that were detrimental to the test specimens under the test conditions.

Environment*	Pertinent Observations During Test	Conclusions
10. Magnesium chlorate water, (low concentrations)	Pitting commenced at 19 days; moderate to severe pitting at 79 days	Unacceptable
11. Magnesium chlorate water, (high concentrations)	Pitting commenced at 15 days; severe at 79 days	Unacceptable
12. TCA—Water	Metal action commenced at 10 days; extreme action at 30 days; specimen lost all properties at 60 days	Unacceptable
28. Bordeaux mixture	Extreme discoloration, finish dulled; no metal damage	Good
29. DDT—dust, (paste)	Pitting commenced at 30 days; active metal deterioration at 79 days	Unacceptable
30. Toxaphene-sulfur dust	Pitting commenced at 21 days; destructive pitting at 30 days	Unacceptable
32. Arsenates (paste)	Very slight pitting at 79 days	Good
33. Commercial fertilizer (8-8-8)	Pitting commenced at 15 days, specimen lost all properties at 60 days	Unacceptable

\* Refer to Table B for solution concentrations.

TABLE 3

**Test Specimen:** 4130 chrome-molybdenum steel with no applied finish.

**Test Conditions:** Tests conducted at room temperature under partial submergence.

**Results:** The length of the tests varied from 6 to 39 days, depending upon the severity of chemical action on the metal. Most generally, the time necessary for severe corrosion was 6 days. The xylene-kerosene solutions inhibited corrosive action as long as the sample remained submerged. It may be definitely concluded that the 4130 chrome-molybdenum steel is highly susceptible to all of the water-carrier solutions that were tested.

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TABLE 4

**Test Specimen:** 4130 chrome-molybdenum steel sheet with no applied finish.

**Test Conditions:** Specimens were exposed continuously to the atmosphere while being treated with the testing medium at three-day intervals.

**Results:** All environments affected the test specimens. 4130 chrome-molybdenum steel must have a protective coating.

**Fungicides—**Bordeaux mixture, Carbamates (high and low concentration), Sulfur.

**Defoliant—**Magnesium chlorate (high and low concentration).

**Fertilizers—**Ammonium nitrate, Liquid fertilizer (high and low concentrations), 8-8-8 commercial fertilizer.

The following controls were also used in this work: Water, kerosene, xylene, kerosene + xylene mixture.

The corrosive effects of these various chemicals were tested on the following materials used in aircraft structures and distribution equipment.

#### Metals

24S-T3 Alclad aluminum alloy sheet  
4130 Chrome-molybdenum steel sheet  
Brass alloy sheet  
Monel metal sheet  
Type 302 stainless steel sheet

#### Plastics

Clear vinyl plastic sheet  
Clear Plexiglass sheet  
\*Polyester resin "A". This is a plastic reinforced by interwoven fiberglass.  
\*\*Polyester resin "B". A similar polyester resin plastic reinforced by interwoven fiberglass

#### Doped Fabrics

Butyrate doped fabric, (Heavy Titenine)  
Butyrate doped fabric, (Light Titenine)  
Butyrate doped fabric, (USA Randolph)

Table A gives a complete list of the paint or finish systems as used in this project.

All partially submerged tests were conducted at room temperature and based on an aircraft spray coverage of four gallons per acre. All chemical concentrations per acre, as taken from entomology laboratory data and agricultural chemical manufacturer's reports, were calculated on a proportional level to correspond to a pound per acre basis (Table B). Submerged tests were carried out in 125 milliliter glass containers with specimen coupons that extended into both the liquid and vapor regions of the vessel. Concentrations were maintained at values actually used in practice. In cases where high and low concentrations were employed both extremes were tested.

\*Polyester resin "A"—Manufactured by Beetle Plastic Corporation with the tradename "Bonate."

\*\*Polyester resin "B"—Supplied by Fabri Mold Tool Engineering Company, and composed of Selectron 5003, manufactured by the Pittsburgh Plate Glass Company, and a Garyist sun cure catalyst manufactured by the Thelco Corporation of Los Angeles, California.

TABLE 5

**Test Specimen:** Half-hard brass sheet with no applied finish.

**Test Conditions:** Tests conducted at room temperature under partial submergence.

Environment*	Time (Days)	Physical Change of Sample		Pertinent Observations During Test	Conclusions
		Vapor	Liquid		
1. Aldrin	73	No Change	No Change	Sample unaffected	Excellent
2. Chlordane	73	No Change	No Change	Sample unaffected	Excellent
3. TEPP	73	No Change	Pitting	Interfacial corrosion at 42 days	Good
4. Toxaphene	73	No Change	No Change	Sample unaffected	Excellent
5. Aramite	73	No Change	No Change	Sample unaffected	Excellent
6. BHC	73	No Change	No Change	Sample unaffected	Excellent
7. Potassium cyanate	42	Weak	Brittle	Metallic reaction commenced at 1 day severe at 10 days	Unacceptable
8. Potassium cyanate	28	Weak	Broke	Metallic reaction commenced at 1 day; severe at 6 days	Unacceptable
9. Sodium cyanamide	73	Pitting	Interfacial pitting	Interfacial action commenced at 39 days	Fair; good at 35 days
10. Magnesium chlorate	73	No Change	Pitting at interfacial	Interfacial action commenced at 39 days	Good at 35 days
11. Magnesium chlorate	73	Slight pitting at edges	Slight interfacial pitting	Edge pitting commenced at 53 days	Good at 73 days
12. TCA	73	No Change	Interfacial pitting	Interfacial breakdown began at 45 days	Excellent to 40 days
13. Liquid fertilizer	73	No Change	No Change	Protective green film formed at 3 days	Excellent
14. Liquid fertilizer	73	No Change	No Change	Protective green film formed at 3 days	Excellent
15. Ammonium sulfamate	39	Scaling	Broke at interface	Interfacial damage commenced at 4 days	Unacceptable
16. 2,4-D	73	No Change	No Change	Sample unaffected	Excellent
17. Parathion	73	No Change	Slight surface cleaning	Very slight pitting in liquid phase at 24 days; slight interfacial action	Good
18. 2,4,5-T	73	No Change	Scaling at interface	Liquid level action commenced at 39 days	Fair
19. Carbamate	73	No Change	No Change	Sample unaffected	Excellent
20. Carbamate	73	No Change	No Change	Sample unaffected	Excellent
21. Water	73	No Change	Interfacial scaling	Definite spot interfacial scaling at 39 days	Fair
22. Kerosene	73	No Change	No Change	Sample unaffected	Excellent
23. Xylene	73	No Change	No Change	Sample unaffected	Excellent
24. DDT	73	No Change	No Change	Sample unaffected	Excellent
25. Aldrin	45	No Change	Slight interfacial scaling	Scaling commenced at 20 days	Fair
26. Heptachlor	45	No Change	No Change	Sample unaffected	Excellent
27. Dieldrin	45	No Change	Very slight interfacial action	Action at interface commenced at 39 days	Excellent at 45 days
28. Ammonium nitrate	45	No Change	No Change	Very slight interfacial action	Excellent

\* Refer to Table B for solution concentrations.

TABLE 6

**Test Specimen:** Half-hard brass sheet with no applied finish.  
**Test Conditions:** Specimens were exposed continuously to the atmosphere while being treated with the testing medium at three-day intervals.

**Note:** The following table is a summary of the environments that were detrimental to the test specimens under the test conditions.

Environment*	Pertinent Observations During Test	Conclusions
7. KCNO-low concentration	Heavy protective film at 20 days; no damage	Excellent
9. Sodium cyanamide water	Dark discoloration at 6 days; very slight pitting at 79 days	Good
12. TCA—water	Surface action and pitting commenced at 45 days; metal damage at 79 days	Unacceptable
15. Ammonium sulfamate	Extreme metal action commenced at 10 days; sample destroyed at 50 days lost all flexibility, strength, etc.	Unacceptable
29. DDT—dust paste	Scaling evident at 11 days; extreme scaling, discoloration at 79 days—black	Unacceptable
30. Toxaphene—sulfur dust	Scaling evident at 10 days; discoloration, black	Unacceptable
33. Commercial fertilizer (8-8-8)	Extreme metal action at 7 days; sample disintegrated at 60 days	Unacceptable

\* Refer to Table B for solution concentrations.

TABLE 7

**Test Specimen:** Monel sheet, standard cold rolled, with no applied finish.

**Test Conditions:** Tests conducted at room temperature under partial submergence. Length of test was 82 days.

**Note:** Monel metal demonstrated good resistance to all of the testing environments. Some of the testing media resulted in permanent discoloration (the effect was pronounced in the liquid region) and one solution showed a slight pitting effect as shown below.

Environment*	Pertinent Observations During Test	Conclusions
1. Aldrin—solvent solution	(black)	Excellent
2. Chlordane—water solution	(Grey-black)	Excellent
5. Aramite—water solution	(black)	Excellent
7. Potassium cyanate solution (low concentration)	(green)	Excellent
8. Potassium cyanate solution (high concentration)	(green) slight pitting	Acceptable
9. Sodium cyanamide—water solution	(black)	Excellent
20. Carbamate solution (high concentration)	(black)	Excellent

\* Refer to Table B for solution concentrations.

TABLE 8

**Test Specimen:** Monel sheet, standard cold rolled, with no applied finish.

**Test Conditions:** Specimens were exposed continuously to the atmosphere while being treated with the testing medium at three-day intervals.

**Note:** Corrosion resistance of the Monel sheet was excellent except for the following materials (the metal damage as noted was very slight).

Environment*	Pertinent Observations During Test	Conclusions
7. Potassium cyanate, water low concentrations	Slight pitting commenced at bottom of sample at 60 days	Acceptable
8. Potassium cyanate, water high concentrations	Pitting commenced at 50 days	Acceptable
28. DDT—dust—paste	Metal discolored at 20 days; pitting commenced at 40 days; definite pitting at 60 days	Acceptable
30. Toxaphene—sulphur dust—paste	Active pitting at 40 days	Acceptable
32. Arsenates	Pitting commenced at 50 days	Acceptable

\* Refer to Table B for solution concentrations.

Micrometer measurements were obtained for all specimens with an applied finish although visual effects were easily noted.

The atmospheric tests were run using the same concentration system as the submerged samples, although in this phase of work all dusts and solid fertilizers were applied in a paste form. All tests were run using the alternate dip method. Every three days the samples were placed in contact with the testing medium and then replaced in the atmospheric environment. The tests were conducted at varying temperatures and humidity over a period of 79 days.

Rotational atmospheric tests were conducted on samples that were contacted with one solution, allowed to remain under that environment in the atmosphere for three days, then washed clean, dried and retreated with another solution. These tests were conducted for 79 days using 26 different solutions.

Observations and micrometer measurements were taken daily for the first week on all tests. After the first week, readings were taken at greater time intervals.

When a test with an applied finish was concluded, the coupon was washed, allowed to dry and tested for bonding properties. A wire brush or metal scraper was used in conjunction with this phase of the procedure. If the finish was in good condition, micrometer measurements were made and the sample was noted for swelling effects. In general, the visual observations were sufficient to determine if a finish was acceptable.

### Aspects of Reproducibility

Because of the severe finish attacks shown by such insecticides as parathion, TEPP, Aramite, heptachlor and Dieldrin, several test samples were run under the same conditions and solution concentrations. Results on this type were taken as an average of all samples run. When an early blistering effect was noted on a coupon, an improper finish application might be suspected; therefore another coupon was started on the test procedure. However, when in all cases every coupon exhibited a proper finish application no test data had to be deleted.

### Results and Discussion

All results presented in this report are from data

TABLE 9

**Test Specimen:** Stainless steel, type 302, with no applied finish.  
**Test Conditions:** Tests conducted at room temperature under partial submergence. Test duration 73 days.

**Results:** All samples were unaffected. Excellent resistance was shown in each environment.

TABLE 10

**Test Specimen:** Stainless steel, type 302, with no applied finish.  
**Test Conditions:** Specimens were exposed continuously to the atmosphere while being treated with the testing medium at three-day intervals.

Environment*	Pertinent Observations During Test	Conclusions
30. Toxaphene and sulphur dust (paste)	Minute pitting commenced at 60 days; same at 79 days	Fair

\* Refer to Table B for solution concentrations.



TABLE 11

**Test Specimen:** Prepolymerized furan finish (Table A) applied to 24S-T3 Alclad aluminum alloy.

**Test Conditions:** Test conducted at room temperature under partial submergence. A scratch was made on one side of each specimen to simulate finish damage under actual operating conditions.

Environment*	Time (Days)	Physical Change of Sample		Pertinent Observations During Test	Conclusions
		Vapor	Liquid		
1. Aldrin	82	No Change	No Change	Sample unaffected	Excellent
2. Chlordane	82	No Change	No Change	Sample unaffected	Excellent
3. TEPP	5	No Change	Bonding lost	Finish destroyed; no bonding	Unacceptable
4. Toxaphene	82	No Change	No Change	Sample unaffected	Excellent
5. Aramite	3	No Change	Finish soft-no bonding	Finish destroyed completely; soft at 24 hours	Unacceptable
6. BHC	82	No Change	No Change	Sample unaffected	Excellent
7. Potassium cyanate	61	No Change	Pin blisters	Slight pin blisters at 40 days	Acceptable
8. Potassium cyanate	82	No Change	No Change	Sample unaffected	Excellent
9. Sodium cyanamide	82	No Change	No Change	Sample unaffected; metal pitting at scratch finish showing good bonding	Excellent
10. Magnesium chlorate	82	No Change	No Change	Sample unaffected	Excellent
11. Magnesium chlorate	82	No Change	No Change	Sample unaffected	Excellent
12. TCA	33	Metal reaction	Metal reaction	Reacted violently with metal at scratch; finish showed good bonding; will be excellent if no scratches occur	Excellent as to finish; TCA and aluminum react severely
13. Liquid fertilizer	82	No Change	No Change	Sample unaffected	Excellent
14. Liquid fertilizer	82	No Change	No Change	Sample unaffected	Excellent
15. Ammonium sulfamate	82	No Change	No Change	Sample unaffected	Excellent
16. 2,4, D	82	No Change	No Change	Sample unaffected	Excellent
17. Parathion	3	No Change	Finish destroyed	Finish soft at 24 hours; completely off at 3 days	Unacceptable
18. 2,4,5-T	82	No Change	No Change	Sample unaffected	Excellent
19. Carbamate	70	No Change	Very slight blistering	Pin blistering commenced at 19 days; acceptable to 50 days	Acceptable to 50 days
20. Carbamate	70	No Change	Very slight blistering	Pin blistering commenced at 19 days; acceptable to 50 days	Acceptable to 50 days
21. Water	65	No Change	Very slight blistering	Slight pin blistering commenced at 20 days; acceptable protection	Good
22. Kerosene	82	No Change	No Change	Sample unaffected	Excellent
23. Kerosene	82	No Change	No Change	Sample unaffected	Excellent
24. DDT	82	No Change	No Change	Sample unaffected	Excellent
25. Dieldrin	2	Blistering	Finish removed	Finish soft at 24 hours; completely destroyed at 2 days	Unacceptable
26. Heptachlor	2	Blistering	Finish removed	Finish soft at 24 hours; completely destroyed at 2 days	Unacceptable
27. Ammonium nitrate	60	No Change	No Change	Sample unaffected	Excellent

\* Refer to Table B for solution concentrations.

TABLE 12

**Test Specimen:** Prepolymerized furan finish (Table A) applied to 4130 chrome molybdenum steel.

**Test Conditions:** Tests conducted at room temperature under partial submergence. A scratch was made on one side of each specimen to simulate finish damage under actual operating conditions.

Environment*	Time (Days)	Physical Change of Sample		Pertinent Observations During Test	Conclusions
		Vapor	Liquid		
1. Aldrin	82	No Change	No Change	Sample unaffected	Excellent
2. Chlordane	60	No Change	Blistering	Excellent at 45 days; blistering at 50 days	Fair
3. TEPP	6	Peeling	Split	Severe blistering commenced at 48 hours	Unacceptable
4. Toxaphene	82	No Change	No Change	Sample unaffected	Excellent
5. Aramite	6	No Change	Finish removed	Finish soft at 2 days	Unacceptable
6. BHC	82	No Change	No Change	Sample unaffected	Excellent
7. Potassium cyanate	65	No Change	Very slight blistering	Lost bonding at scratch at 48 days; blistering at 35 days	Good
8. Potassium cyanate	60	No Change	Blistering	Blistering commenced at 20 days; creep at 53 days	Fair
9. Sodium cyanamide	65	No Change	Blistering	Excellent at 35 days; blistering commenced at 40 days	Acceptable
10. Magnesium chlorate	65	No Change	Blistering at scratch	Very slight blistering only at 20 days; excellent bonding	Good
11. Magnesium chlorate	75	No Change	Creep at scratch	Creep commenced at scratch at 60 days; could be used extensively if no surface damage arose	Excellent
12. TCA	70	No Change	Creep at scratch	Creep commenced at 53 days; excellent bonding elsewhere	Acceptable
13. Liquid fertilizer	65	No Change	Slight creep at scratch	Creep commenced at 53 days; good bonding elsewhere	Excellent
14. Liquid fertilizer	82	No Change	Slight blistering at scratch	Slight blistering at scratch at 60 days	Excellent
15. Ammonium sulfamate	82	No Change	Interface damage	Interfacial damage commenced at 70 days	Excellent at 65 days
16. 2,4, D	82	No Change	No Change	Sample unaffected	Excellent
17. Parathion	6	No Change	Finish removed	Finish soft at 2 days; completely destroyed at 6 days	Unacceptable
18. 2,4,5-T	65	Slight blistering	Blistering	Blistering at scratch at 35 days; no protection at 60 days	Acceptable at 35 days
19. Carbamate	45	Very slight blistering	Severe blistering	Blistering commenced at 13 days; easy to peel at 30 days	Acceptable at 20 days
20. Carbamate	45	Very slight blistering	Severe blistering	Blistering commenced at 13 days; easy to peel at 30 days	Acceptable at 20 days
21. Water	60	No Change	Scratch blistering	Blistering at scratch at 20 days; good bonding elsewhere	Excellent
22. Kerosene	82	No Change	No Change	Sample unaffected	Excellent
23. Xylene-kerosene	82	No Change	No Change	Sample unaffected	Excellent
24. DDT + solvent	82	No Change	No Change	Sample unaffected	Excellent
25. Aldrin + water	60	No Change	Pebble appearance	Blistering commenced at all areas at 30 days; unacceptable at 35 days	Good at 25 days

\* Refer to Table B for solution concentrations.

obtained over the entire testing periods. In order to evaluate the specimens at the end of the test a rating system was necessary. The conclusions as used were not presented in a highly technical manner because the overall object was to determine if the finish would or would not stand up under the different environments.

For the conclusion ratings as shown in the tables at the end of the report, the following ratings were adhered to:

Excellent—Sample unaffected physically although a color change may have taken place.

Good—Finish showing very slight blisters, or creep at scratch areas. Finish not easy to scrape off. Good metal protection.

Fair or Acceptable—Excellent for a limited period of time, finish still protecting at end of test. Slight blistering although finish shows good bonding over 90 percent of area.

Unacceptable—Finish lost bonding rapidly, severe blisters, charred surface, severe splitting, finish disintegration, no protection.

#### Metals With No Applied Finish

This group of specimens was composed of 24S-T3 Alclad aluminum alloy, 4130 chrome-molybdenum steel, half-hard brass sheet, Monel and Type 302 stainless steel.

**Aluminum alloy, 24S-T3 Alclad**—The 24S-T3 aluminum alloy was rapidly and severely attacked in the

TABLE 13

**Test Specimen:** Prepolymerized furan finish (Table A) applied to 4130 chrome-molybdenum steel.

**Test Conditions:** Specimens were exposed continuously to the atmosphere while being treated with the testing medium at three-day intervals. A scratch was made on one side of each specimen to simulate finish damage under actual operating conditions.

**Note:** The following is a summary of the environments that were detrimental to the test specimens under the test conditions.

Environment*	Pertinent Observations During Test	Conclusions
3. TEPP—water	Slight blisters formed at 60 days	Good at 50 days
11. Magnesium chlorate, water—(high concentration)	Very slight action at scratch at 70 days	Excellent at 60 days
12. TCA—water	Finish showing only slight creep at scratch area	Excellent at 65 days

\* Refer to Table B for solution concentrations.

TABLE 14

**Test Specimens:** Prepolymerized furan finish (Table A) applied to 24S-T3 Alclad aluminum alloy.

**Test Conditions:** Specimens were exposed continuously to the atmosphere while being treated with the testing medium at three-day intervals. A scratch was made on one side of each specimen to simulate finish damage under actual operating conditions.

**Note:** The following is a summary of the environments that were detrimental to the test specimens under the test conditions.

Environment*	Pertinent Observations During Test	Conclusions
33. Commercial fertilizer (8-8-8)	Finish blistered near scratch at 45 days; severe damage at 60 days	Excellent when no scratch areas arise

\* Refer to Table B for solution concentrations.

partially submerged tests by sodium cyanamide and TCA herbicides (Table 1). A variety of aluminum alloys was tested with TCA and all demonstrated severe corrosion. Recent work by Alquist and Wasco\* run on 50 percent solutions of TCA show that corrosion can be inhibited or prevented by mixtures of sodium chromate or sodium dichromate.

\*F. N. Alquist and J. L. Wasco. The Inhibition of Sodium Trichloroacetate Weed-Killer Solution. *Corrosion*, Vol. 8, No. 12, 410-411 (1952) Dec.

TABLE 15

**Test Specimen:** Epoxy-based finish (Table A) applied to 24S-T3 Alclad aluminum alloy.

**Test Conditions:** Tests conducted at room temperature under partial submergence. A scratch was made on one side of each specimen to simulate finish damage under actual operating conditions.

Environment*	Time (Days)	Physical Change of Sample		Pertinent Observations During Test	Conclusion
		Vapor	Liquid		
1. Aldrin	80	No Change	No Change	Sample unaffected	Excellent
2. Chlordane	12	No Change	Blistering	Finish blistered badly at 3 days; no protection at 5 days	Unacceptable
3. TEPP	4	Loose	Loose	Finish lost all bonding at 3 days submersion	Unacceptable
4. Toxaphene	80	No Change	No Change	Sample unaffected	Excellent
5. Aramite	80	No Change	No Change	Sample unaffected	Excellent
6. BHC	80	No Change	No Change	Sample unaffected	Excellent
7. Potassium cyanate	80	No Change	No Change	Sample unaffected; brittle when dry, out solution	Excellent in solution
8. Potassium cyanate (high concentration)	80	No Change	No Change	Sample unaffected; brittle when dry, out of solution	Excellent in solution
9. Sodium cyanamide	4	Blistering	Severe blistering	Severe blistering at 24 hours; no protection	Unacceptable
10. Magnesium chlorate	80	No Change	Slight blistering	Slight blisters at 30 days; good protection	Acceptable
11. Magnesium chlorate	80	No Change	No Change	Sample unaffected	Excellent
12. TCA	80	No Change	Blistering	Excellent for 60 days; blisters developed at 65 days	Excellent if no abrasives arise
13. Liquid fertilizer	80	No Change	No Change	Sample unaffected	Excellent
14. Liquid fertilizer	80	No Change	No Change	Sample unaffected	Excellent
15. Ammonium sulfamate	80	No Change	No Change	Sample unaffected	Excellent
16. 2,4-D	80	No Change	No Change	Sample unaffected	Excellent
17. Parathion	80	No Change	Slight blistering	Blistering commenced at several points at 18 days; same at 80 days	Unacceptable
18. 2,4,5-T	80	No Change	Slight blistering	Very slight blisters at 20 days; no change; good protection	Acceptable
19. Carbamate	80	No Change	No Change	One small blister at 60	Excellent
20. Carbamate	80	No Change	No Change	Sample unaffected	Excellent
21. Water	80	No Change	No Change	Sample unaffected	Excellent
22. Kerosene	80	No Change	No Change	Sample unaffected	Excellent
23. Xylene	80	No Change	No Change	Sample unaffected	Excellent
24. DDT	80	No Change	No Change	Sample unaffected	Excellent

\* Refer to Table B for solution concentrations.

Approximately 0.7 percent sodium dichromate will stop all corrosion on solutions near 50 percent TCA. Tests on this project were not run using the sodium dichromate or sodium chromate although investigations on this work should prove valuable.

The aluminum alloy was also susceptible to water

TABLE 16

**Test Specimen:** Epoxy-based finish (Table A) applied to 4130 chrome-molybdenum steel.

**Test Conditions:** Tests conducted at room temperature under partial submergence. A scratch was made on one side of each specimen to simulate finish damage under actual operating conditions.

Environment*	Time (Days)	Physical Change of Sample		Pertinent Observations During Test	Conclusions
		Vapor	Liquid		
1. Aldrin	80	No Change	No Change	Sample unaffected	Excellent
2. Chlordane	80	No Change	No Change	Sample unaffected	Excellent
3. TEPP	2	Loose	Lost all bonding	Finish disintegrated	Unacceptable
4. Toxaphene	80	No Change	No Change	Sample unaffected	Excellent
5. Aramite	65	No Change	Creep at scratch	Excellent bonding; slight soft at scratch 58 days	Good
6. BHC	80	No Change	No Change	Sample unaffected	Excellent
7. Potassium cyanate (low concentrations)	70	No Change	Scratch creep	Finish offered acceptable resistance but cracked and became brittle when removed from solution	Acceptable while submerged
8. Potassium cyanate	80	No Change	Scratch creep	Finish offered acceptable resistance but cracked and became brittle when removed from solution	Acceptable while submerged
9. Sodium cyanamide	80	No Change	No Change	Sample unaffected	Excellent
10. Magnesium chlorate	80	No Change	No Change	Sample unaffected	Excellent
11. Magnesium chlorate	80	No Change	No Change	Sample unaffected	Excellent
12. TCA	65	No Change	Easily chipped	Severe creep at scratch at 18 days; acceptable through 40 days	Fair
13. Liquid fertilizer	75	No Change	Slight blistering	Creep at scratch with blistering; excellent for 50 days	Excellent at 50 days
14. Liquid fertilizer	60	No Change	Slight blistering	Creep at scratch with blistering; excellent for 50 days	Excellent for 50 days
15. Ammonium sulfamate	80	No Change	No Change	Sample unaffected	Excellent
16. 2,4-D	80	No Change	No Change	Sample unaffected	Excellent
17. Parathion	75	No Change	Slight creep at scratch	Slight scratch creep only; resistance good	Excellent
18. 2,4,5-T	80	No Change	Slight creep at scratch	Slight scratch creep only; resistance good	Excellent
19. Carbamate	80	No Change	No Change	Slight blisters at scratch only; good bonding	Excellent
20. Carbamate	80	No Change	Creep at scratch	Creep at scratch excessive at 80 days	Acceptable
21. Water	80	No Change	No Change	Slight creep at scratch	Excellent
22. Kerosene	80	No Change	No Change	Sample unaffected	Excellent
23. Kerosene	80	No Change	No Change	Sample unaffected	Excellent
24. DDT	80	No Change	No Change	Sample unaffected	Excellent

\* Refer to Table B for solution concentrations.

after a period of 24 days. Pitting started at the liquid-vapor interface and spread rapidly.

In the atmospheric tests the 24S-T3 Alclad aluminum alloy was totally destroyed by the TCA solution, commercial fertilizer (8-8-8) and magnesium chlorate solution. The DDT dust, Toxaphene-sulfur dust, Bordeaux mixture and the arsenate dust caused metal pitting, although a longer testing period would be necessary to evaluate the results properly (Table 2).

**Steel, 4130 chrome-molybdenum**—From data collected on 4130 chrome-molybdenum steel it may be concluded definitely that an applied finish is mandatory for this steel. The average time necessary for severe metal action in the partially submerged tests was six days (Table 3). It was attacked very rapidly under all environments in the atmospheric tests (Table 4).

**Brass, half-hard sheet**—The half-hard brass was severely attacked in the partially submerged tests by the cyanates, cyanamides and sulfamate compounds. Rapid interfacial destruction was noted on many samples after 30 days. See Table 5 for complete data.

The brass alloy demonstrated essentially identical destructive properties in atmospheric and submerged tests. Heavy scaling and metal destruction were caused by TCA, the sulfamates, commercial fertilizer (8-8-8), DDT dust and Toxaphene-sulfur dust. The cyanates and cyanamides formed heavy protective films at 20 days' exposure, thereby eliminating metal destruction (Table 6).

**Monel**—Monel was excellent in the partially submerged tests with the exception of the highly concentrated potassium cyanate solution which gave a slight pitting effect. Although several chemicals discolored Monel metal, no major destruction was evident (Table 7).

Under an atmospheric environment Monel exhibited higher corrosion rates than during submerged

TABLE 17

**Test Specimen:** Epoxy-based finish (Table A) applied to 24S-T3 Alclad aluminum alloy.

**Test Conditions:** Specimens were exposed continuously to the atmosphere while being treated with the testing medium at three-day intervals. A scratch was made on one side of each specimen to simulate finish damage under actual operating conditions.

**Note:** The following table is a summary of the environments that were detrimental to the test specimens under the test conditions.

Environment*	Pertinent Observations During Test	Conclusions
3. TEPP—water	Finish commenced peeling at 50 days; primer loose, no bonding; destroyed at 60 days	Unacceptable
7. KCNO (low concentrations)	Crack marks indicating brittleness at 70 days	Unacceptable
8. KCNO (high concentrations)	Crack marks indicating brittleness at 70 days	Unacceptable
12. TCA—water	Finish brittle at 50 days active creep at 79 days	Unacceptable
15. Ammonium sulfamate	Brittle at 79 days; cracked	Excellent at 50 days
33. Commercial fertilizer (8-8-8)	Blistered at scratch at 20 days; blistered at all areas at 40 days; destroyed at 43 days	Unacceptable

\* Refer to Table B for solution concentrations.



TABLE 18

**Test Specimen:** Vinyl plastic-base finish (Table A) applied to 24S-T3 Alclad aluminum alloy.

**Test Conditions:** Tests conducted at room temperature under partial submergence. A scratch was made on one side of each specimen to simulate finish damage under actual operating conditions.

Environment*	Time (Days)	Physical Change of Sample		Pertinent Observations During Test	Conclusions
		Vapor	Liquid		
1. Aldrin	83	No Change	No Change	Sample unaffected	Excellent
2. Chlordane	83	No Change	No Change	Sample unaffected	Excellent
3. TEPP	6	No Change	Loose	Poor adherence to sample; loose	Unacceptable
4. Toxaphene	83	No Change	No Change	Sample unaffected	Excellent
5. Aramite	6	No Change	Loose	Became soft at 2 days	Unacceptable
6. BHC	83	No Change	No Change	Sample unaffected	Excellent
7. Potassium cyanate	83	No Change	No Change	Sample unaffected	Excellent
8. Potassium cyanate	83	No Change	No Change	Sample unaffected	Excellent
9. Sodium cyanamide	83	No Change	No Change	Sample unaffected	Excellent
10. Magnesium chlorate	83	No Change	No Change	Sample unaffected	Excellent
11. Magnesium chlorate	70	Slight blistering	Creep	Creep at scratch at 13 days; blister at 45 days	Good; excellent if scratch free
12. TCA	36	Severe creep	Metal disintegration	TCA reacted with metal at scratch at 4 days; finish overcome at 15 days	TCA and aluminum should have no contact; TCA should have inhibitor
13. Liquid fertilizer	83	No Change	No Change	Sample unaffected	Excellent
14. Liquid fertilizer	83	No Change	No Change	Sample unaffected	Excellent
15. Ammonium sulfate	83	No Change	No Change	Sample unaffected	Excellent
16. 2,4-D	83	No Change	No Change	Sample unaffected	Excellent
17. Parathion	6	Loose	Loose	Became soft at 2 days; destroyed at 6 days	Unacceptable
18. 2,4,5-T	83	Blistering	No Change	Very slight blister in vapor phase at 40 days	Excellent
19. Carbamate	18	No Change	Loose	All samples lost bonding at 3 to 5 days; 4 samples run and all destroyed or bonding lost	Unacceptable
20. Carbamate	83	No Change	No Change	Sample unaffected	Excellent
21. Water	83	No Change	Slight pin blisters	Very slight pin blisters at 21 days; no change; good bonding further	Good
22. Kerosene	83	No Change	No Change	Sample unaffected	Excellent
23. Xylene	83	No Change	No Change	Sample unaffected	Excellent
24. DDT	83	No Change	No Change	Sample unaffected	Excellent
25. Aldrin	65	No Change	No Change	Sample unaffected	Excellent
26. Dieldrin	3	Loose	Loose	Finish lost bonding at 24 hours; finish destroyed completely at 3 days	Unacceptable
27. Ammonium nitrate	65	No Change	No Change	Sample unaffected	Excellent

\* Refer to Table B for solution concentrations.

TABLE 19

**Test Specimen:** Vinyl plastic-base finish (Table A) applied to 4130 chrome-molybdenum steel.

**Test Conditions:** Test conducted at room temperature under partial submergence. A scratch was made on one side of each specimen to simulate finish damage under actual operating conditions.

Environment*	Time (Days)	Physical Change of Sample		Pertinent Observations During Test	Conclusions
		Vapor	Liquid		
1. Aldrin	70	No Change	No Change	Sample unaffected	Excellent
2. Chlordane	70	No Change	No Change	Slight pin blisters at 55 days; no creep; good protection	Acceptable
3. TEPP	24	No Change	Loose	Finish soft at 15 days; destroyed at 24 days	Unacceptable
4. Toxaphene	70	No Change	No Change	Sample unaffected	Excellent
5. Aramite	6	No Change	Soft	Very poor adherence to sample, disintegrated	Unacceptable
6. BHC	70	No Change	No Change	Sample unaffected	Excellent
7. Potassium cyanate	70	No Change	Scratch creep	Scratch creep continued through test; blistering commenced at 15 days (slight)	Fair at 70 days
8. Potassium cyanate (high)	70	No Change	Slight creep	Very slight creep at scratch, edge, slight blistering at scratch	Good metal protection at 70 days
9. Sodium cyanamide	70	No Change	Very slight pin blistering at scratch	Very slight blistering commenced at 55 days; good protection	Acceptable at 70 days
10. Magnesium chlorate (low)	70	No Change	Blistering at scratch	Very slight blistering commenced at 6 days; slight creep at 51 days; severe at 65 days	Acceptable at 50 days
11. Magnesium chlorate	70	Blistering	Blistering	Finish showing high creep after 36 days, blistering	Acceptable at 30 days
12. TCA	55	Blistering	Excess creep	Pin blisters commenced at 21 days; high creep at 36 days	Acceptable at 21 days
13. Liquid fertilizer	70	Blistering	Creep blistering	Blistering commenced at 21 days; creep at 36 days	Acceptable at 50 days
14. Liquid fertilizer	70	Blistering	Slight blistering	Slight creep at 51 days; good protection	Acceptable at 70 days
15. Ammonium sulfate	70	No Change	No Change	Interfacial blistering commenced at 60 days; active at 70 days	Excellent to 60 days
16. 2,4-D	70	No Change	Very slight blistering	Very slight blistering commenced at 55 days; no change to 70 days	Good
17. Parathion	1	No Change	Loose	Completely destroyed in 12 hours	Unacceptable
18. 2,4,5-T	53	Blistering	XS blistering	Excellent at 15 days; blistering at 21 days; severe blistering at 51 days	Unacceptable
19. Carbamate (low)	70	No Change	Very slight blistering	Very slight pin blistering at 21 days; no change at 70 days, good protection	Good
20. Carbamate	53	Slight blistering	Blistering	Creep at scratch and bare edge at 15 days; bonding broke down at 36 days	Good at 30 days
21. Water	53	Slight blistering	Blistering	Blistering commenced at 21 days; excess at 50 days	Acceptable at 40 days
22. Kerosene	70	No Change	No Change	Sample unaffected	Excellent
23. Xylene + Kerosene	70	No Change	No Change	Sample unaffected	Excellent
24. Xylene + Kerosene + DDT	70	No Change	No Change	Sample unaffected	Excellent
25. Aldrin + water	50	No Change	No Change	Very slight blistering at 30 days	Acceptable

\* Refer to Table B for solution concentrations.

tests. Pitting commenced at 50 days upon all specimens contacted with DDT dust. Toxaphene-sulfur dust, potassium cyanates and the arsenate dust insecticides (Table 8).

**Stainless steel, Type 302**—In the partially submerged tests Type 302 stainless steel demonstrated complete resistance to corrosion throughout the test period (Table 9).

In the atmospheric tests Type 302 stainless steel exhibited excellent resistance to all materials with the exception of Toxaphene and sulfur dust insecticides. Minute pitting commenced on the steel at 60 days although only very slight metal damage was evident (Table 10).

### Finishes Applied to Metal

This portion of the investigation was primarily concerned with the effects of the various agricultural chemicals on basic finishes. Hence, the first three finishes as described in Table A were applied only

TABLE 20

**Test Specimen:** Vinyl plastic-base finish (Table A) applied to 4130 chrome-molybdenum steel.

**Test Conditions:** Specimens were exposed continuously to the atmosphere while being treated with the testing medium at three-day intervals. A scratch was made on one side of each specimen to simulate finish damage under actual operating conditions.

**Note:** The following table is a summary of the environments that were detrimental to the test specimens under the test conditions.

Environment*	Pertinent Observations During Test	Conclusions
8. Potassium cyanate (high concentration)	Bonding near scratch weak at 70 days	Good
10. Magnesium chlorate (low concentration)	Very slight effect at scratch; creep	Good
11. Magnesium chlorate (high concentration)	Very slight effect at scratch; creep	Good
12. TCA—water	Metal action at scratch at 10 days; blister commenced at 55 days; breakdown at 79 days	Unacceptable
13. Ammonium sulfamate	Finish soft at 73 days; slight metal damage at 79 days	Excellent at 65 days

\* Refer to Table B for solution concentrations.

TABLE 21

**Test Specimen:** Vinyl plastic-base finish (Table A) applied to 24S-T3 Alclad aluminum alloy.

**Test Conditions:** Specimens were exposed continuously to the atmosphere while being treated with the testing medium at three-day intervals. A scratch was made on one side of each specimen to simulate finish damage under actual operating conditions.

**Note:** The following table is a summary of the environments that were detrimental to the test specimens under the test conditions.

Environment*	Pertinent Observations During Test	Conclusions
5. Aramite—water	Bonding lost at 50 days; no metal damage	Excellent at 45 days
11. Magnesium chlorate (high concentration)	Metal action at scratch; finish excellent, no creep at 79 days	Excellent
12. TCA—water	Finish broke down at 24 days; metal action with solution	Unacceptable
15. Ammonium sulfamate	Slight soft finish at 79 days	Excellent at 79 days
20. DDT—dust—(paste)	Creep at 50 days; scratch effect creep	Excellent at 45 days
33. Commercial fertilizer (8-8-8)	Finish blister at 20 days; no protection at 30 days; destroyed at 45 days	Unacceptable

\* Refer to Table B for solution concentrations.

to the 24S-T3 Alclad aluminum alloy and the 4130 chrome-molybdenum steel. The other two finishes tested, the modified chlorinated rubber formulation and the liquid Neoprene coating, were tested on an aluminum alloy and 4130 chrome-molybdenum steel, respectively.

**Furan Finish**—The prepolymerized furan coating preceded by a wash primer of the polyvinyl butyral

TABLE 22

**Test Specimen:** A modified chlorinated rubber finish (Table A) applied to an aluminum alloy.

**Test Conditions:** Tests conducted at room temperature under partial submergence. The finish was applied to one side only of the test specimens.

Environment*	Time (Days)	Physical Change of Sample		Pertinent Observations During Test	Conclusions
		Vapor	Liquid		
1. Aldrin	31	No Change	No Change	Sample unaffected	Excellent
2. Chlordane	24	No Change	Soft	Finish began to soften at 20 days; off at 24 days	Unacceptable
3. TEPP	3	No Change	Soft	Coating became loose; bonding destroyed	Unacceptable
4. Toxaphene	31	No Change	No Change	Sample unaffected	Excellent
5. Aramite	3	No Change	No Change	Poor adherence to metal	Unacceptable
6. BHC	31	No Change	No Change	Sample unaffected	Excellent
7. Potassium cyanate	5	No Change	Brittle	Sample lost color at 3 days; became brittle, easy to peel	Unacceptable
8. Potassium cyanate	5	No Change	Brittle	Sample lost blue color at 3 days; became brittle easy to peel	Unacceptable
9. Sodium cyanamide	5	No Change	Brittle	Lost color at 3 days; brittle at 5 days	Unacceptable
10. Magnesium chlorate	31	No Change	No Change	Sample unaffected	Excellent
11. Magnesium chlorate	31	No Change	No Change	Sample unaffected	Excellent
12. TCA	7	No Change	Aluminum deteriorated	TCA attacked the aluminum vigorously; finish broke at 7 days	Good if no abrasions
13. Liquid fertilizer	31	No Change	No Change	Sample unaffected	Excellent
14. Liquid fertilizer	31	No Change	No Change	Sample unaffected	Excellent
15. Ammonium sulfamate	31	No Change	No Change	Sample unaffected	Excellent
16. 2,4-D	31	No Change	No Change	Sample unaffected	Excellent
17. Parathion	3	No Change	Loose	Finish lost all bonding, became loose at 3 days	Unacceptable
18. 2,4,5-T	31	No Change	No Change	Sample unaffected	Excellent
19. Carbamate	31	No Change	No Change	Sample unaffected	Excellent
20. Carbamate	31	No Change	No Change	Sample unaffected	Excellent
21. Water	31	No Change	No Change	Sample unaffected	Excellent
22. Kerosene	31	No Change	No Change	Sample unaffected	Excellent
23. Xylene	31	No Change	No Change	Sample unaffected	Excellent
24. DDT	31	No Change	No Change	Sample unaffected	Excellent
25. Dieldrin	1	No Change	Loose	Finish lost bonding	Unacceptable
26. Heptachlor	1	No Change	Loose	Finish lost bonding	Unacceptable

\* Refer to Table B for solution concentrations.

TABLE 23

**Test Specimen:** Liquid Neoprene finish (Table A) on 4130 chrome-molybdenum steel.

**Test Conditions:** Tests conducted at room temperature under partial submergence. A scratch was made on one side of each specimen to simulate finish damage under actual operating conditions.

**Results:** The finish was not acceptable in any submerged environment over a period of 6 to 10 days.

TABLE 24

**Test Specimen:** Liquid Neoprene finish (Table A) on 4130 chrome-molybdenum steel.

**Test Conditions:** Specimens were exposed continuously to the atmosphere while being treated with the testing medium at three-day intervals. A scratch was made on one side of each specimen to simulate finish damage under actual operating conditions.

**Note:** The following table is a summary of the environments that were detrimental to the test specimens under the test conditions.

Environment*	Pertinent Observations During Test	Conclusions
5. Aramite in water	Softening at 50 days	Excellent at 45 days
7. KCNO (low concentration)	Lost bonding at 65 days	Excellent at 50 days
8. KCNO (high concentration)	Lost bonding at 60 days	Excellent at 45 days
9. Sodium cyanamide	Lost bonding at 55 days	Excellent at 50 days
11. Magnesium chlorate (high concentration)	Lost bonding at 50 days; metal damage at 79 days	Excellent at 40 days
12. TCA—water	Lost bonding and properties at 30 days	Unacceptable
15. Ammonium sulfamate	Finish blistered at 30 days; metal damage at 79 days	Unacceptable
16. 2,4-D, ammonium salt	Slight softening at 72 days	Excellent at 65 days
28. Bordeaux mixture	Slight creep at scratch at 56 days; good protection	Good
30. Toxaphene—sulphur (paste)	Paint lost bonding at 50 days	Excellent at 45 days
33. Commercial fertilizer	Slight softening at 75 days; no creep at 79 days	Excellent at 70 days

\* Refer to Table B for solution concentrations.

TABLE 25

**Test Specimen:** Clear vinyl plastic sheet with no applied finish.

**Test Conditions:** Tests conducted at room temperature under partial submergence. Length of tests was 53 days.

Environment*	Pertinent Observations During Test
3. TEPP—water	Discolored white at 17 days; slight swelling at 39 days.
5. Aramite—water	Discolored white at 10 days; swollen at 15 days; very soft, pliable at interface.
17. Parathion—water	Discolored cloudy yellow at 2 days; swollen badly at 15 days; weak at interface.

\* Refer to Table B for solution concentrations.

TABLE 26

**Test Specimen:** Clear plexiglas sheet with no applied finish.

**Test Conditions:** Tests conducted at room temperature under partial submergence. Length of tests was 53 days.

Environment*	Pertinent Observations During Test
3. TEPP—water—3%	Slight swelling at 40 days
7. Potassium cyanate water—2%	Slight yellow discoloration 20 days
8. Potassium cyanate water—4%	Slight yellow discoloration at 20 days
9. Sodium cyanamide water—4%	Slight yellow discoloration at 36 days
12. TCA—water 1.25 lb./gallon	Cloudy, white at 6 days; swelling at 15 days; lost all clearness, soft and gummy
17. Parathion—water 0.5%	Slight yellow discoloration at 30 days

\* Refer to Table B for solution concentrations.

group exhibited the best overall finish (Tables 11 and 12). The finish was attacked vigorously by only five solutions in the partially submerged tests: TEPP, Aramite, Parathion, Dieldrin and Heptachlor. This finish bonded very well to both 24S-T3 Alclad aluminum and chrome-molybdenum steel.

In the atmospheric tests the furan finish on 4130 chrome-molybdenum steel also showed excellent bonding properties with all solutions contacted. As the test progressed this finish remained intact and no swelling was noted. TEPP solution caused very slight blisters at 60 days although good metal protection was still available at 79 days exposure (Table 13).

The furan finish on 24S-T3 Alclad aluminum was attacked only by the commercial fertilizer (8-8-8). Destruction of the metal under the finish caused the surface finish to disrupt and crack. Bonding as demonstrated by this finish on aluminum was excellent to the point that TCA did not react with the metal through the surface scratch. A longer testing period should possibly be employed with this paint system (Table 14).

Atmospheric results show that the above destructive compounds are practically inactive when washed from the samples after use. This implies that a furan finish would be highly acceptable for all compounds tested if the hopper or spray tank was washed after each use.

**Epoxy-Based Finish**—The epoxy-finish on 24S-T3 Alclad aluminum alloy and 4130 chrome-molybdenum steel was generally acceptable but showed very brittle properties when removed from a solution. This was especially true with the cyanates in both the immersed and atmospheric tests. The epoxy-base finish on 24S-T3 Alclad aluminum alloy exhibited brittle properties to the extent that surface cracking began. Parathion and Aramite did not attack this finish readily and it may be stated that the epoxy finish was the only applied finish that resisted these chemicals. Tables 15, 16, 17 give complete data on this finish.

**Vinyl Plastic-Base Finish**—The vinyl plastic-base finish, preceded by one coat of a chromate wash primer and one coat of an intermediate finish, was applied to both the 24S-T3 Alclad aluminum and the 4130 chrome-molybdenum steel. This finish covers with a very low film thickness dimension and bonds very well to steel and aluminum when the surface is de-greased and washed properly. It is ideal for aircraft in that the surface is very smooth, pliable, and shock resistant. The finish is readily attacked, however, by Aramite, TEPP, Parathion, 2,4,5-T, Dieldrin, carbomated and Heptachlor solutions. Bonding properties are not rigid when a surface scratch arises and a creep with metal exposure will result with a majority of materials tested. The complete results of the partially submerged tests are given in Tables 18 and 19.

In the atmospheric tests the vinyl-based finish on 4130 chrome-molybdenum steel was attacked very rapidly by the TCA solution. Poor bonding was

caused by concentration and low environment (Table 2). 24S-T3 with the bonding coupon environment system does not finish through.

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Under on 4130 excellent p end of sulfamate. At 50-65 the bonding phene, s trations) concentr (Table 2).

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caused by the potassium cyanate solution (high concentration) and magnesium chlorate solutions (high and low concentrations). The ammonium sulfamate environment softened the finish at 73 days exposure (Table 20).

24S-T3 Alclad aluminum alloy used in conjunction with the vinyl-based finish showed relatively poor bonding properties after a scratch was placed on the coupon. Table 21 gives a complete summary of the environments that were detrimental to this paint system. It should be noted that the TCA solution does not actually destroy or react with the vinyl finish but reacts with the metal under the finish through the scratch area.

**Modified Chlorinated Rubber Finish**—The modified chlorinated rubber on aluminum was generally unacceptable in solutions that showed destructive properties on other finishes. This finish was tested in a partially submerged environment only and therefore no data on the atmospheric aspects are available (Table 22).

**Liquid Neoprene Finish**—The Neoprene finish on 4130 chrome-molybdenum steel is unacceptable for any length under submerged conditions (Table 23).

Under atmospheric conditions the Neoprene finish on 4130 chrome-molybdenum steel demonstrated excellent properties in all solutions for 30 days. At the end of the 30-day period the TCA and ammonium sulfamate solutions caused slight blistering effects. At 50-65 days the following environments loosened the bonding at the scratch areas: Aramite, Toxaphene, sulfur dust, cyanates (high and low concentrations), cyanamides, magnesium chlorate (high concentration), 2-4-D and the Bordeaux mixture (Table 24).

### Plastics Partially Submerged

**Plexiglas and Vinyl Sheet**—Tables 25 and 26 describe the chemical environments that were destructive to vinyl plastic sheet and Plexiglas. TEPP, Aramite and Parathion solutions attacked the vinyl plastic in much the same manner that they attacked the vinyl plastic-base applied finish. Softening effects were noted rather quickly with Parathion, whereas Aramite and TEPP commenced to discolor and soften the coupons at 10 to 17 days respectively. The Plexiglas sheet was destroyed in six days by the TCA solution. All properties of a clear plastic were lost by the test material. The cyanates, cyanamides and Parathion solutions caused discoloration in the Plexiglas but no softening was evident.

**Polyester Resin**—The two makes of fiberglass-reinforced polyester plastic were tested for 40 and 50 days, respectively. Excellent resistance to all solutions was demonstrated during this period (Table 27).

### Doped Fabrics

Complete data on all doped fabric tests are available in Table 28.

### Rotational Tests

Rotational test data were accumulated for a period of 79 days and during that period 26 various solutions were applied to the materials and finishes tested. Table 29 gives a complete summary of these results. As shown in the table, three finishes demonstrated excellent properties: furan finish, epoxy finish and the vinyl finish. This type of test is a rigorous test

TABLE 27

**Test Specimen:** Fiber glass-reinforced polyester resin "A" (Bonate) with no applied finish.

**Test Conditions:** Tests conducted at room temperature under partial submergence. The length of the tests was 40 days.

**Results:** The test specimens offered excellent resistance to all of the environments. There were no swollen effects, discolorations, or softening effects at the edges.

**Test Specimen:** Fiber glass-reinforced polyester resin "B" with no applied finish.

**Test Conditions:** Tests conducted at room temperature under partial submergence. Length of the tests was 50 days.

**Results:** A very slight whitening of the surface of the specimen submerged in TEPP was observed at 28 days. No further change noted at 50 days.

TABLE 28

**Test Specimen:** Butyrate doped fabric with three different finishes (light titenine, heavy titenine and U.S.A. Randolph) was tested.

**Test Conditions:** Tests conducted at room temperature under complete submergence. Evaluations were made after the specimens were dried, following their removal from the test environments.

Environments*	Finishes Affected	Observations
3. TEPP	Light Titenine	Soft at 20 days
7. Potassium cyanate (low concentration)	U.S.A. Randolph	Blister at 22 days
17. Parathion solution	All	Surface soft commenced from 12 to 20 days
25. Dieldrin	Light Titenine	Soft
25. Dieldrin	U.S.A. Randolph	Blister

\* Refer to Table B for solution concentrations.

TABLE 29

### Rotational Atmospheric Tests

**Test Conditions:** Samples were alternately treated with one solution, allowed to hang for 3 days, then washed with water, and retreated with another solution, etc. This test was conducted for 79 days, using 26 various solutions commencing with Aldrin, chlordane, etc.

Material or Finish	Observations During Test
24S-T3 Alclad aluminum alloy with no applied finish	Pitting at 45 days; (TCA) continued at 79 days
4130 chrome-molybdenum steel with no applied finish	Moderate oxide film formation
Half-hard brass with no applied finish	Permanent green discoloration, commenced with potassium cyanate solutions
Monel metal with no applied finish	Permanent green discoloration, commenced with potassium cyanate solutions
Type 302 stainless steel with no applied finish	Excellent at 79 days exposure
Furan finish on 4130 chrome-molybdenum steel	Excellent at 79 days exposure
Furan finish on 24S-T3 Alclad aluminum alloy	Excellent at 79 days exposure
Epoxy-based finish on 24S-T3 Alclad aluminum alloy	Excellent at 79 days exposure
Vinyl plastic-base finish on 24S-T3 Alclad aluminum alloy	Slight pitting at 75 days near scratch
Vinyl plastic-base finish on 4130 chrome-molybdenum steel	Excellent at 79 days exposure
Liquid neoprene finish on 4130 chrome-molybdenum steel	Showed slight blistering and softening at 60 days

but a longer time period should be used. The data on these tests do indicate that all material should be cleaned thoroughly after use.

### Conclusions and Recommendations

The results of this investigation indicate that none of the applied coatings tested provided a perfect corrosion-free finish against all of the agricultural chemicals. The furan finish with the butyral wash primer, however, demonstrated excellent resistance to the vast majority of chemicals tested. Wider recognition of this type of finish should be observed because its physical properties are suitable for aircraft. The furan finish as used in this project was easily sprayed, brushed, or dipped, and no trouble was encountered during application.

Of the structural materials tested, only two, Type 302 stainless steel and polyester plastic reinforced with fiberglass, showed complete resistance to all of the solutions investigated. Either of these materials should be very satisfactory for tank or hopper construction if weight requirements can be met.

Stainless steel appears to be the best material available for corrosion-free piping and plumbing systems. Monel, which is easier to machine, showed up reasonably well, however. Brass, aluminum alloy

and chrome-molybdenum steel were all destroyed by certain of the agricultural chemicals.

Since most of the tanks and hoppers already constructed are of an aluminum alloy, the possibility of using an inhibitor with such extreme corrosives as TCA should be investigated. It is recommended that tests be set up using various percentages of sodium chromate and sodium dichromate in solution with TCA. Aluminum of all types should be tested. This particular inhibitor will possibly work with such compounds as sodium cyanamide also.

The rotational tests, in which the specimens were treated with each of 26 chemicals for 3-day periods and washed with water in between, indicated that most all of the materials would stand up reasonably well if they were cleaned thoroughly after each use.

### Acknowledgment

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# Solution of Cathodic Protection Interference Problems\*

By FRANCIS W. RINGER

## Introduction

ONE OF THE MOST important aspects involved in the engineering of a cathodic protection installation on a sub-surface metallic structure is that of determining the extent of possible interference on neighboring structures which are not primarily considered as being a part of the cathodic protection system. It is the duty of the designing engineer to consider the possibility of creating interference on neighboring structures by his application of cathodic protection because he can be held responsible for damage caused thereby. It can easily happen that the engineering of a given project can be made more complicated when remedial measures are required to eliminate interference, but nevertheless, the job is not finished until these measures are taken. It behooves the engineer to apply the golden rule.

There are several methods of solving interference problems and excellent papers concerning cathodic protection and interference problems have been written.<sup>1,2</sup> It is the purpose of this article to explain the use of the network method in solving these problems.

## The Network Method

The network method was originated approximately twenty years ago by the late Dr. J. M. Pearson as a result of his studies in connection with the solution of electrolysis problems created by stray railway currents on underground pipelines and cables.<sup>3</sup> Many years of experience obtained from the application of Dr. Pearson's method by a large number of engineers has shown that the network method is well adapted to the solution of cathodic protection and interference problems as well as those due to stray currents.

## Fundamental Bases

The derivation of the network method is based upon three fundamental bases: First, neglecting the effect of polarization, the resistance to earth of a buried pipeline or cable remains practically constant with respect to time. Except in the case of shallowly buried systems during extended periods of drought, many tests over periods of several years have shown that the resistance to earth of a given line or cable varies only within narrow limits which can be tolerated from an engineering standpoint. The significance of this is that the internal resistance (resistance through earth) between two or more neighboring underground structures is constant. A commonly observed manifestation of this is, in general, the



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## Abstract

When an external source of power with associated ground bed is used to provide cathodic protection to an underground structure, the possibility is presented of creating accelerated corrosion on neighboring structures which are not a part of the cathodic protection system due to the flow of interference currents on these neighboring structures. This article describes a method of obtaining data which will permit the extent of interference to be determined before permanent cathodic protection installations are made. And, if the need for a bond between structures to prevent interference is indicated the bond resistance can be calculated on an engineering basis. Data obtained by the use of this method are of engineering accuracy which can be obtained in minimum of field time, thus eliminating cut and try methods and the need for extensive surveys made before and after permanent installations are completed.

The method was evolved approximately 20 years ago by the late Dr. J. M. Pearson of the Sun Oil Co. in connection with his development of engineering methods for the investigation and control of stray currents on underground structures. Since cathodic protection interference currents are of the same nature as stray currents with the exception that they are controllable and of steady value, the method has been found to be very useful in cathodic protection work. In developing this method Dr. Pearson based his work upon the fact that the resistance through the earth between structures and the resistance between a structure and earth in any given location is constant and thus can be treated as such mathematically. Upon this basis underground structures can be considered as an electrical network permitting solution of problems relating to cathodic protection, interference, etc., by measuring the network constants at the proper location. Simple mathematical treatment of the data thus obtained will provide required solutions most easily and quickly.

A brief discussion is given concerning the proper location of a ground bed in order to minimize the effect of interference on foreign structures. It is explained that when the ground bed is improperly located, interference currents may be set up on the foreign structure which cannot be eliminated by the use of a bond between structures. There is generally a location at which a ground bed can be placed that will result in minimum interference current flow on foreign structures and which is in the direction permitting resolution by bonding.

constant relationship between voltage and current output of a cathodic protection rectifier before appreciable deterioration of the ground bed sets in.

The second fundamental basis is that since only direct currents are involved in corrosion and cathodic

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protection circuits, the relationship between voltage and currents at any point in an underground electrical network created by neighboring buried pipes and cables, is linear or directly proportional. In other words, the use of Ohm's Law is perfectly valid in studying conditions on an underground system. The significance of this is that if one ampere of cathodic protection current will result in a change of .1 volt between structure and earth at any given location, increasing or decreasing this current by a certain amount will cause a proportional increase or decrease in structure to earth voltage at the same location. The relationship between voltage change between structure and environment at any given point and current flow between structure and environment causing the change, is fixed in accordance with Ohm's Law. This is true regardless of whether or not the voltage change is positive or negative and whether or not the source of current is connected to the structure of interest to provide cathodic protection, or is connected to a foreign structure so that interference current flows on the structure of interest.

Likewise, the voltage change between neighboring, but unconnected, structures holds a fixed relationship with current output from a cathodic protection rectifier which is connected to one of the structures involved and which causes a change in voltage between structures. Again, if the structures happen to be electrically connected, the current flow between these structures holds a fixed relationship with the rectifier current causing this flow.

The third fundamental basis is the concept of superposition of currents and voltages. According to this concept, if an interference current, or current causing corrosion, is flowing along a pipeline and a cathodic protection or bond current is caused to flow in order to produce a counterbalancing effect, the manifestation of each of these currents separately—such as IR drops along the pipeline or cable, voltages between pipeline or cable and earth, etc.—are the same as if that current existed alone. Thus the total effect of the two currents together is the algebraic sum of each. If one or the other of the currents can be interrupted or caused to vary in a measurable amount, the effect of that current alone can be determined by measuring the change in total effect simultaneously with current change. In words of the late A. V. Smith, one current is painted red in order that it may be distinguished from any others flowing in the same circuit.

These characteristics of the electrical network created by neighboring underground structures provide the corrosion engineer with a very convenient method of solving problems relating to cathodic protection and associated interference upon an engineering basis rather than upon cut and try methods. Once a given criterion for protection has been adopted, the current magnitude needed to protect a given line, or the amount of line that can be protected with a given magnitude of current can be determined; the extent of interference upon foreign structures can be determined; and data can be taken which will permit bond resistance requirements to be calculated.

### Test Procedure

The fixed relationships between currents and voltages, which are called network constants, at various points in the underground network are easily measured in the field and these constants then used algebraically to arrive at the particular solution desired. The simplest example of this would be the problem of determining how much rectifier current would be required to change the structure-to-soil voltage on a coated pipeline to the commonly employed value of .85 volt at a point ten miles from the rectifier. If the residual, or natural, pipe-to-soil voltage is .6 volt, this means that sufficient rectifier current must flow to cause a change in pipe-to-soil voltage of .25 volts at the location ten miles distant.

The test procedure would consist of installing a temporary test anode or ground bed at the location where the permanent ground bed is to be installed and connecting a test current battery or generator between the pipeline and ground bed. This test current circuit is then alternately made and broken rhythmically either by hand operation or by use of an automatic switch which will allow test current to flow at periodic intervals. The magnitude of test current can be of any convenient value which will produce a good readable deflection of the meter measuring pipe-to-soil voltage at the ten mile point. Simultaneous readings are then taken of test current and change in pipe-to-soil voltage caused by the test current in sufficient number to provide a valid average.

The pipe-to-soil voltage change in volts is then divided by the test current in amperes to produce the network constant. In accordance with Ohm's Law the unit of this constant can be called "ohms" since it is a ratio of volts to amperes, but it is more realistically called "volts per ampere" because the aspect of "ohms" has no practical significance except from a mathematical standpoint. In other words, this constant is the voltage change that would be produced by one ampere of test current. In order to determine the magnitude of current required to produce a given voltage change, this required change is divided by the network constant. For example from the original problem, if the required voltage change is .25 volt and it is found that 20 amperes of test current changes the pipe-to-soil voltage .4 volt thus producing a network constant of .02 volt per ampere, the magnitude of rectifier current needed to produce a pipe-to-soil voltage of .85 at the point ten

miles distant would be  $\frac{.25}{.02} = 12.5$  amperes.

### Effect of Polarization

It was implied at the beginning of this discussion that the derivation of the network method disregards the effect due to polarization. This is because the effect of polarization on a sub-surface structure is to increase the resistance between structure and earth, but since polarization is a function of current magnitude, time, and environmental characteristics, its effect cannot be predetermined by simple test methods. However, the use of network methods and

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analyses are not thereby rendered invalid for the reason that changes due to polarization are generally relatively small, and they are always of such an effect that they provide a safety factor. Intelligent observation by the corrosion engineer under a given set of conditions will provide experience whereby valid predictions can be made for future comparable conditions.

### The Interference Problem

The method just shown for the determination of cathodic protection current requirement also can be employed for the solution of interference problems. However, first things should come first and in connection with interference this involves the location of the rectifier ground bed with respect to the configuration of the structures involved when it is found that a cathodic protection installation will create interference on neighboring structures. In other words, the location of the ground bed with reference to neighboring structures which are not to be made a part of the cathodic protection system is the first step to be considered if interference on the foreign structures is to be at a minimum.

### Anode Location

When a buried anode is connected to the positive terminal of a dc source, the potential of the earth surrounding the anode is raised, the magnitude of increase depending upon the distance from the anode. The maximum increase of potential is in the earth immediately adjacent to the anode and as distance from the anode increases, the rise of earth potential decreases. This change of earth potential in the area surrounding the anode is called the anode potential gradient. If a metallic structure such as a buried pipeline or cable traverses this gradient, current will flow from earth to structure and will flow along the structure away from the vicinity of the anode and from the structure back to earth at points remote from the anode.

Conversely, if an underground metallic structure is connected to the negative terminal of a dc source the potential of the earth surrounding the structure will be depressed, the magnitude again being an inverse function of distance from the structure. This change in earth potential is called the cathode potential gradient and a pipeline or cable lying in this gradient will be subjected to current flow from remote points along the structure which will be discharged from the structure to earth in the vicinity of the cathode.

Thus, it is obvious that when a ground bed is constructed as part of a system to provide cathodic protection to an underground structure, this ground bed can cause interference current to flow on neighboring structures, the magnitude and polarity of the interference current depending upon the location of the ground bed with reference to the neighboring structures. If these structures are influenced more by the cathode than by the anode gradient, interference current will flow from remote points along the struc-

ture toward the cathode and discharge of this current to earth in the vicinity of the cathode can be prevented by installing a metallic connection called a bond between the foreign structures and the cathode or structure under protection. However, if the foreign structures are influenced more by the anode than by the cathode gradient, interference current will flow radially or endwise to be discharged back to earth at remote points. This flow of endwise current to earth is sometimes difficult to prevent because the discharge areas are generally so remote from the cathode or the structure under protection that the use of bonding as a means of control is precluded.

When a cathodic protection system is designed, in nearly all cases the underground structures that may be affected either adversely or beneficially by the cathodic protection current are in place and cannot be moved. Therefore, because the only remaining freedom left to the corrosion engineer is in the location of the ground bed this should be considered fully. Preliminary tests should be made to determine the effects upon foreign structures as well as on the structure to be protected which are caused by various locations of the ground bed. These tests are not difficult to make and do not require extensive test anodes or ground beds. An excellent article which covers this situation in more detail has been written by A. V. Smith.<sup>2</sup> A little additional time spent and test work done in this respect can easily prevent later complications and abnormal work and expenditures.

### The Bond Problem

After the best location has been selected for the ground bed and it is desired to determine the value of current that will be required to flow from the foreign structure to the structure under protection through a bond connection, test data are taken by the use of which calculations can be made of bond current required to prevent interference and the value of bond resistance needed to produce that magnitude of current. In order to make the required tests, it is not necessary nor usually advisable to wait until the final cathodic protection system is installed. A test anode placed at the same location chosen for the permanent ground bed, and a test current source consisting of a portable dc generator or batteries can be used.

While a convenient value of test current is being thrown on and off between the test anode and the structure to be protected, a survey is conducted along the foreign structure to determine the location of maximum exposure that must be cleared by the bond installation. This is done by reading the change in ground voltage at various points along the foreign structure caused by a given value of test current. The location of maximum exposure is the location where the foreign structure goes positive to earth by the greatest magnitude and it is this location where test data are taken for bond calculations.

In terms of network constants, the formula for bond resistance is:

$$R_B = \frac{R_{2,1}}{\beta_{2,1}} - R_{1,1} \text{ ohms}$$

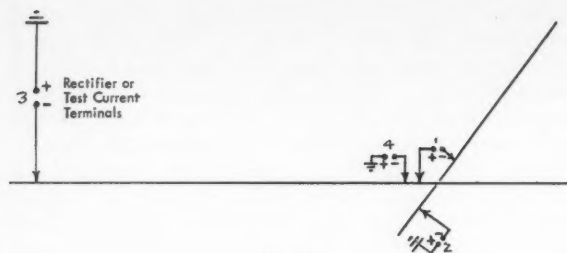


Figure 1

where  $R_{2,1}$  = Change in ground voltage on the foreign structure caused by one ampere of current between structures. This is called the ground voltage coupling.

$\beta_{2,1}$  = Ratio of ground voltage change on the foreign structure, to voltage change between the foreign structure and protected structure caused by the test current flow between the test anode and line to be protected.

$R_{1,1}$  = Internal resistance (resistance through earth) between the structures at the bond location. This is the ratio of voltage change between structures to current between structures.

It will be noted that the numbered subscripts represent is numbered terminals where data are taken, the first subscript denoting the terminals where the data used for the numerator of the ratio is taken and the second subscript for the denominator. For example, Figure 1 shows a representative configuration of two pipelines, one of which is to be cathodically protected. A bond is to be connected between the two to prevent interference on the foreign line. The numbered terminals shown represent the terminals of the meters used for making observations. The network constant  $R_{2,1}$ , for example, is obtained by reading the change in voltage at terminals 2 ( $V_{g2}$ ) simultaneously with current at terminals 1 ( $I_1$ ) which causes the change. The change is voltage,  $\Delta V_{g2}$ , is then divided by the current  $I_1$ , to give  $R_{2,1}$  which is the voltage change at terminals 2 per ampere of current at terminals 1.

The formula given for bond current is derived as follows: With a meter connected at terminals 2 in Figure 1 to measure pipe-to-soil voltage, it can be seen that with the rectifier in operation the reading given by the meter which will be called  $V_{g2}$ , for ground voltage, is the algebraic sum of two parts or components, one being the voltage, called  $\alpha_2$ , that would be read between pipe and reference electrode if the rectifier were shut down and the other being the exposure value caused by interference from rectifier operation.

Since direct current is involved with its linear relationships, there is a fixed relationship between the change in  $V_{g2}$  caused by interference current from the rectifier and the change in voltage,  $V_1$  between structures at terminals 1 due to this same rectifier current. This relationship will be called  $2\beta_{2,1}$  and it is the percentage of the change in voltage at terminals 1 that appears as voltage change at terminals 2. The value of  $\beta$  is determined by reading simultaneously the change in voltage at terminals 1 and 2,

as the rectifier or test current at terminals 3 is turned on and off and then taking the ratio  $\frac{\Delta V_{g2}}{\Delta V_1}$ , where

$\Delta$  means change. Another method of computing  $\beta$

would be by taking the ratio  $\frac{R_{2,2}}{R_{1,2}}$  which is voltage change at terminals 2 per ampere of test current at terminals 3 divided by the voltage change at terminals 1 per ampere of test current at terminals 3. Thus the meter measuring ground voltage at terminals 2 can be represented as  $V_{g2} = \alpha_2 + \beta_{2,1}V_1$ .

If a bond is now connected between lines so that bond current can flow, a third component of ground voltage is introduced which will influence the meter reading at terminals 2. Since the effect of bond current flowing from the foreign line to the protected line has the effect of providing cathodic protection to the foreign line by depressing its potential with respect to earth, it will have the opposite effect upon the foreign line from rectifier current, thus it will have the opposite sign or polarity. With the test terminal polarities as shown in Figure 1,  $R_{2,3}$  would be negative and  $R_{2,1}$  would be positive.

With the rectifier in operation to cause interference on the foreign line and a bond between lines in place to allow bond current to flow, the ground voltage being measured at terminals 2 can now be represented as follows:

$$V_{g2} = \alpha_2 + \beta_{2,1}V_1 + R_{2,1}I_1 \text{ volts} \quad (1)$$

The third term,  $R_{2,1}I_1$ , expresses the change in ground voltage at terminals 2 caused by bond current flow between lines.  $R_{2,1}$  represents the voltage change per ampere of bond current, therefore if this is multiplied by the total bond current,  $I_1$ , the product,  $R_{2,1}I_1$ , represents the total voltage change. Equation (1) is called the ground voltage equation.

Since the last two terms in equation (1) have opposite effects upon the foreign line, the final effect upon the line will be the same as if no interference current exists if these values are made equal in magnitude. This can be done by equating the two and solving algebraically for  $I_1$ , which is the critical value of bond current required to nullify interference effects:

$$\beta_{2,1}V_1 = R_{2,1}I_1$$

$$\text{Therefore } I_1 = \frac{\beta_{2,1}V_1}{R_{2,1}} \text{ amperes} \quad (2)$$

This is the value of  $I_1$ , or bond current, that is required to cancel the exposure effect due to interference.  $\beta_{2,1}$  and  $R_{2,1}$  are network constants which are easily determined from field test and  $V_1$  is the voltage change between lines caused by interference current from the rectifier and this also is determined from field test. A good method of doing this would be to measure voltage change between lines,  $\frac{\Delta V_1}{I_1}$ , simultaneously with rectifier current,  $I_1$ . The ratio  $\frac{\Delta V_1}{I_1}$ , then is the voltage change per ampere of recti-



fier current. When this ratio is multiplied by total rectifier current, the total voltage change between lines is determined.

The next step in solving the bond problem is to determine the value of bond resistance required, with  $V_1$  known, to pass the proper value of bond current,  $I_1$ . It is well known that when the terminals of a cell or battery are connected to some value of external resistance to allow current to flow, the magnitude of current will be the ratio of open circuit battery voltage to the sum of external resistance and internal battery resistance. The same situation is presented by the two pipelines which are to be bonded. Terminals 1 represent the battery terminals,  $V_1$  represents the open circuit voltage,  $R_{1,1}$  which is the internal resistance between lines represents the internal battery resistance and the bond resistance,  $R_B$ , represents the external resistance. The bond current thus is represented by:

$$I_1 = \frac{V_1}{R_B + R_{1,1}} \text{ amperes} \quad (3)$$

Since equations 2 and 3 are equal, they can be equated and solved for  $R_B$ :

$$\frac{\beta_{2,1} V_1}{R_{2,1}} = \frac{V_1}{R_B + R_{1,1}} \quad (4)$$

$$\text{Therefore } R_B = \frac{R_{2,1}}{\beta_{2,1}} - R_{1,1} \text{ ohms} \quad (5)$$

This is the critical value of bond resistance needed to allow the proper magnitude of bond current to flow which will just cancel or nullify the exposure effect from interference current. Only the three network constants shown on the right side of equation (5) are needed to solve the bond problem and these are easily and quickly obtained by field test. Any value of resistance less than that given by equation (5) will allow more than the critical value of bond current to flow with the result that cathodic protection will be obtained on the foreign line in the vicinity of terminals 2 and any value of bond resistance higher than that given by equation (5) will not permit sufficient bond current to flow to eliminate the total exposure, although it will be decreased.

Equation (5) shows that the critical value of bond resistance is independent of the voltage changes at terminals 1 and 2, as well as the magnitude of rectifier current. This condition holds, however, only in the case where there is no residual or galvanic voltage between lines and this very often is not the case. It is seen that the only voltage involved in equation (4) is  $V_1$  which is due to rectifier operation and that this cancels out in solving for  $R_B$ . When a residual voltage is present between lines, equation (3) takes the form:

$$I_1 = \frac{E_1 + V_1}{R_B + R_{1,1}} \text{ amperes} \quad (6)$$

and equation (4) takes the form:

$$\frac{\beta_{2,1} V_1}{R_{2,1}} = \frac{E_1 + V_1}{R_B + R_{1,1}} \quad (7)$$

Where  $E_1$  represents the residual or galvanic voltage between lines with neither bond nor rectifier current flowing. The solution for  $R_B$ , then is:

$$R_B = \frac{R_{2,1}(E_1 + V_1)}{\beta_{2,1} V_1} - R_{1,1} \text{ ohms} \quad (8)$$

The value of  $V_1$  is obtained as explained previously and the value of  $E_1$  is obtained simply by measuring the voltage at terminals 1 with no rectifier or test current flowing. This can be done by making a visual observation, or if it is suspected that this voltage is not constant, a recording meter is connected to measure the voltage over the desired period of time and the optimum value used in the bond calculations. In most cases it is advisable to make this recording in order that there will be no guess work involved.

Equation (5) shows that when no residual voltage exists between lines, rectifier current may be changed at will, if cathodic protection requirements change with time, without the need for changing the bond resistance. However, equation (8) shows that when a residual voltage does exist, a change in rectifier current will necessitate a change in bond resistance. But because all necessary data were obtained during the original field tests, the new value of bond resistance can be calculated without additional test work.

Another condition which should be considered if a complete solution to the bond problem is to be obtained is the fact that the effect of bond current upon the protected line is to decrease the amount of cathodic protection obtained from the rectifier. This becomes obvious when it is considered that, with respect to the foreign line and direction of bond current flow, the protected line is serving as an anode or ground bed.

The net effect at any given location on the protected line, such as at terminals 4 in Figure 1, is the algebraic sum of cathodic protection effect from rectifier current which will be positive and the interference or exposure effect from bond current which will be negative. The bond effect is determined by connecting the test current generator or battery between lines with polarity such that current will flow from the foreign line through the generator onto the protected line. Because the test current, then, will have the same effect upon each line as bond current, this effect can be measured by obtaining the ground voltage changes per unit current, or the network constants, at the various locations of interest.

With the test current source connected between lines at the same location where the bond is to be connected, a survey should first be conducted along the protected line in order to locate the point of maximum exposure caused by bond current in the same manner that the maximum exposure point was located on the foreign line caused by rectifier current.

This location will be usually, but not necessarily, near the point of bond connection. Let this location be represented by terminals 4 in Figure 1. The network constant,  $R_{4,1}$ , is then obtained. The net change in ground voltage at terminals 4 is then:

$$V_{g4} = I_2 R_{4,2} + I_1 R_{4,1} \text{ volts} \quad (9)$$

$R_{4,3}$  is the change in ground voltage at terminals 4 per unit rectifier current and when this is multiplied by total rectifier current,  $I_3$ , the product gives the component of ground voltage change due to the rectifier.  $R_{4,1}$  is the change in ground voltage at terminals 4 per unit bond current and, likewise, the product of this and total bond current gives the component of change due to bond current. This latter component is of negative polarity as  $R_{4,1}$  would be negative, thus the cathodic protection effect from the rectifier would be decreased.

If it desired to maintain the same change in ground voltage at terminals 4 after the bond is installed as would be obtained without a bond, the rectifier current must be increased by some value above that which would be needed without a bond. However, this would cause an increase in bond current flow, therefore, an exact balance between rectifier current and bond current, or bond resistance, is necessary. The values for balance can be difficult to determine by field experiment but by determining the network constants and using a little algebra, the exact solution can be easily obtained.

Referring to Figure 1, let  $I_3$  be the value of rectifier current required for cathodic protection on the line to be protected without regard for adverse interference effects on the foreign line. This value has been obtained from previous tests by using the particular criterion of protection which appeals to the engineer on the job, such as current value obtained from the null or polarization test, a ground voltage of .85 measured between pipe and copper-copper sulphate half cell placed either over the pipe or at a point out of the ground bed or pipeline potential gradient (remote earth), a change in ground voltage of certain value, current density, effect upon current profile, etc. Let  $I'_3$  be the increased value of rectifier current needed not only to supply the cathodic protection desired but also to overcome the adverse effect from bond current.

After the location of maximum exposure or interference on the foreign line from rectifier current (terminals 2) and the location of maximum exposure on the protected line from bond current (terminals 4), the necessary network constants are measured and these are:  $R_{1,1}$ ,  $R_{2,1}$ ,  $R_{4,1}$ ,  $R_{1,3}$ ,  $R_{2,3}$ ,  $R_{4,3}$ ,  $\beta_{2,1}$ , and  $E_1$ . The expression for ground voltage change at terminals 4 caused by rectifier current with no bond current flowing is given by:

$$V_{g4} = I_3 R_{4,3} \text{ volts} \quad (10)$$

The problem is to determine the increased amount of rectifier current required to produce the same magnitude of cathodic protection at terminals 4 with bond current flowing, as obtained without bond current as

given by equation (10), value of bond current required; and the corresponding bond resistance needed to eliminate exposure on the foreign line. In terms of the network constants, these conditions are stated as follows:

$$I_3 R_{4,3} = I'_3 R_{4,3} + I_1 R_{4,1} \quad (11)$$

$$I'_3 R_{2,3} + I_1 R_{2,1} = 0 \quad (12)$$

In equation (11),  $I_3 R_{4,3}$  represents the positive ground voltage change at terminals 4 caused by the rectifier current without bond current flowing. This is the final value required.  $I'_3 R_{4,3}$  in equation (11) represents the positive change in ground voltage at terminals 4 caused by the increased value of rectifier current, and  $I_1 R_{4,1}$  represents the negative ground voltage change at terminals 4 caused by bond current flow.

Equation (11) states algebraically that the final change in ground voltage at terminals 4 caused by both final rectifier and bond currents must be equal to the change caused by original rectifier current with no bond current flowing. In equation (12),  $I'_3 R_{2,3}$  represents the negative ground voltage change at terminals 2 caused by rectifier current, and  $I_1 R_{2,1}$  represents the positive ground voltage change at terminals 2 caused by bond current. Equation (12) states that the final ground voltage change at terminals 2 caused by both rectifier and bond currents is zero. In other words, the exposure caused by rectifier current is exactly offset by bond current.

Because there are two unknown quantities involved in two equations,  $I'_3$  and  $I_1$ , a simultaneous algebraic solution of these equations gives the required values of rectifier and bond currents:

$$I'_3 = I_3 \frac{R_{4,3} R_{2,1}}{R_{4,3} R_{2,1} - R_{2,3} R_{4,1}} \text{ amperes} \quad (13)$$

$$I_1 = -I_3 \frac{R_{4,3} R_{2,3}}{R_{4,3} R_{2,1} - R_{2,3} R_{4,1}} \text{ amperes} \quad (14)$$

The value  $I'_3$  is obtained in the field by tap adjustment of the rectifier. The value  $I_1$  is obtained by inserting a resistance of proper value in the bond connection between lines at terminals 1. In accordance with the earlier discussion, the current that would flow through a bond at terminals 1 would be:

$$I_1 = -\frac{R_{1,3} I_3 + E_1}{R_B + R_{1,1}} \text{ amperes} \quad (15)$$

Where  $R_B$  is the required bond resistance.  $I_1$  is a negative current for the reason that its effect is to decrease the open circuit voltage at the bond terminals. Since equations (14) and (15) are equal, they can be equated and solved for  $R_B$ . However, the simpler method of solving for  $R_B$  is to solve equation (12) for  $I_1$  and then solve simultaneously with equation (15):

$$I_1 = \frac{-R_{2,3} I'_3}{R_{2,1}} \quad (16)$$

$$R_B = \frac{(R_{1,3} I'_3 + E_1) R_{2,1}}{R_{2,3} I'_3} \text{ ohms} \quad (17)$$

Equations (13) and (17) give the final values required to complete the field installation. If the design and installation has been carried through properly, no change in ground voltage at terminals 2 will be observed as the rectifier and bond circuits are turned on and off simultaneously.

### Field Test Example

An actual example of a field test showing how the

data is taken and recorded and the network constants computed for use in the final calculations is shown later on in this article. Cathodic protection is to be applied to pipeline "A," and terminals 1 represent the test current generator or rectifier terminals. Pipeline "B" is a lateral that ties in to pipeline "A" but since it is not to be protected, the tie-in is made through an insulated flange as shown. Terminals 2 represent the terminals of the voltmeter to be used for measuring voltage between the pipelines. Automobile storage batteries were used as a source of test current at terminals 1 and while this current was turned on and off, a survey of ground voltages on pipeline "B" showed that maximum exposure would occur at terminals 4. Likewise, test current was introduced between lines at terminals 2 and while this was turned on and off a survey along pipeline "A" showed that maximum exposure from bond current would occur at terminals 3. Terminals 5 are at the farthest location on pipeline "A" where protection is to be obtained.

It should be noted that the type of reference electrode or half cell used for making earth contact while measuring ground voltage is immaterial. It is the *change* in ground voltage caused by rectifier and bond current flow that is required and in this case the half cell potential cancels out. A copper-copper sulphate electrode, a steel bar, valve box, or if a vacuum tube voltmeter is used, a weed growing in the earth can be used for the ground connection. The important thing is that the same location be used each time comparative readings or tests are made and that the proper correction factors be applied to voltmeter readings when the internal meter resistance is low in comparison with the external meter circuit resistance.

The problem is to determine the magnitude of rectifier current required to produce a 4-volt change at terminals 5 with bond current flowing from pipeline "B" to pipeline "A" at terminals 2 and to determine the magnitude of bond current and corresponding bond resistance required to eliminate exposure at terminals 4. A 4-volt change is required at terminals 5 in order to eliminate exposure caused by stray railway current. The problem is stated mathematically by two equations:

$$I_1 R_{s1} = V_{g5} + I_2 R_{s2} \quad (18)$$

$$\text{and } I_2 R_{s2} = I_1 R_{s1} \quad (19)$$

Equation (18) states that, at terminals 5, the product of total rectifier current and ground voltage change per ampere of rectifier current is equal to the 4-volt change required ( $V_{g5}$ ) plus the adverse effect caused by bond current. Equation (19) states that the adverse effect at terminals 4 caused by rectifier current will be offset by the beneficial effect caused by bond current.

It will be noted when analyzing the field data appended to this article that  $V_{g5}$  and the network constants,  $R_{s2}$  and  $R_{s1}$ , which describe exposure effects at terminals 3, 4 and 5 are negative. These signs are disregarded, however, when the constants are used in the equations because they are placed on the opposite sides of the equations from the positive con-

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CORROSION CONTROL SURVEY

SHEET NO. 26

COMPANY \_\_\_\_\_

LOCATION \_\_\_\_\_

TESTERS \_\_\_\_\_

DATE \_\_\_\_\_

Open ckt. Voltage  
between pipelines  
( $E_2$ ) = 3 Volts

	$I_1$ #1 100 R.	$V_{g5}$ #2 100 R.	$I_1$ #1 100 R.	$V_{g5}$ #2 100 R.	$I_1$ #1 100 R.	$V_{g5}$ #2 100 R.	$I_1$ #1 100 R.	$V_{g5}$ #2 100 R.	$E_2$ #2 100 R.
+2F.5	+11.3	+2.90	-2.72	+2.90	+2.51	+2.90	-3.69		
0	0	0	-1.8	0	-1.07	0	-3.71		
+2F.5	+11.0	+2.90	-2.63	+2.90	+2.50	+2.90	-3.90		
0	0	0	-1.01	0	-1.8	0	-3.28		
+2F.5	+11.1	0	-2.62	0	-2.68	0	-3.62		
0	0	0	-2.27	+2.90	+2.47	+2.90	-3.66		
+2F.5	+10.9	0	-2.28	0	-0.9	0	-2.2		
0	0	0	-2.55	0	-2.56	0	-2.60		
+2F.1	+10.6	+2.90	-2.99	+2.90	+2.51	+2.90	-3.92		
0	0	0	-2.3	0	0	0	-2.2		
+2F.0	+11.5	0	-2.76	0	-2.51	0	-3.70		
0	0	0	-2.12	+2.90	+2.68	+2.90	-4.15		
+2F.0	+11.2	0	-3.33	0	-2.2	0	-7.1		
0	0	0	-2.44	0	-2.44	0	-3.44		
+2F.1	+10.5	+2.90	-2.50	+2.90	+2.82	+2.90	-4.15		
0	0	0	-1.0	0	-1.65	0	-4.8		
+2F.1	+11.5	0	-2.60	0	-2.17	0	-3.66		
0	0	0	-2.67	+2.90	+2.88	+2.90	-4.02		
+2F.1	+10.8	+2.90	-2.67	+2.90	+2.73	+2.90	-5.0		
0	0	0	-2.55	0	-2.16	0	-3.52		
+2F.0	+10.8	+2.90	-2.49	+2.90	+2.90	+2.90	-3.90		
0	0	0	0	0	-7.0	0	-5.0		
+2F.1	+11.7	0	-2.49	0	-2.20	0	-3.40		
0	0	0	-2.40	+2.90	+2.92	+2.90	-4.10		
+2F.1	+11.8	0	-2.22	0	-7.3	0	-5.8		
0	0	0	-2.66	0	-2.17	0	-3.52		
+2F.1	+10.6	+2.90	-2.55	+2.90	+2.82	+2.90	-4.15		
0	0	0	-1.2	0	-1.81	0	-7.2		
+2F.1	+11.2	0	-2.67	0	-2.40	0	-3.41		
0	0	0	-2.57	+2.90	+2.91	+2.90	-35.58		
$R_{s1}$	+11.3	0	-25.94	0	-33.71	0	-35.58		
$R_{s2}$	282.0	0	290.0	0	170.0	0	289.9		
$R_{s1}$	-4.03	0	-0.874	0	0.824	0	-1.23		
$I_2$	2.41 p.m.	2.46 p.m.	2.46 p.m.	2.53 p.m.	2.53 p.m.	3.51 p.m.	3.51 p.m.		
$I_2$	$V_{g5}$	$V_{g5}$	$V_{g5}$	$V_{g5}$	$V_{g5}$	$V_{g5}$	$V_{g5}$		
$I_2$	#1	#2	#1	#2	#1	#2	#1		
$I_2$	100 R.	100 R.	100 R.	100 R.	100 R.	100 R.	100 R.		
+10.0	+2.76	+11.2	-1.21	+10.2	+3.62	+15.0	-4.08		
0	-3.8	0	-2.1	0	-2.2	0	-1.87		
+10.9	+2.68	+10.7	-1.21	+10.2	+3.65	+15.0	-4.08		
0	-4.2	0	-1.0	0	-2.1	0	-1.78		
+10.8	+2.72	+10.2	-1.22	+10.3	+3.73	+13.5	-3.10		
0	-4.2	0	-0.8	0	-0.8	0	-1.12		
+10.8	+2.73	+10.2	-1.27	+10.7	+3.61	+12.0	-2.70		
0	-4.1	0	-0.3	0	-0.8	0	-1.77		
+11.0	+2.69	+10.4	-1.27	+10.4	+3.69	+11.9	-2.42		
0	-4.1	0	-0.9	0	-0.7	0	-1.73		
+10.2	+2.65	+10.5	-1.28	+10.2	+3.59	+12.0	-2.02		
0	-4.0	0	-0.9	0	-0.8	0	-1.12		
+10.4	+2.81	+9.8	-1.21	+10.1	+3.79	+11.9	-2.60		
0	-4.3	0	-0.6	0	-2.1	0	-1.02		
+11.1	+2.63	+10.2	-1.25	+10.6	+3.65	+12.0	-2.03		
0	-4.8	0	-0.8	0	-1.8	0	-1.30		
+10.6	+2.82	+10.2	-1.23	+10.3	+3.70	+13.0	-2.27		
0	-4.1	0	-0.4	0	0	0	-1.28		
+10.7	+2.71	+10.2	-1.28	+10.3	+3.70	+12.0	-2.50		
0	-4.3	0	-0.1	0	-1.2	0	-0.86		
+10.5	+2.70	+10.2	-1.27	+10.2	+3.71	+12.0	-1.64		
0	-4.7	0	-1.03	0	-3.22	0	-1.72		
$R_{s1}$	+10.5	0	-13.13	0	-37.88	0	-18.72		
$R_{s2}$	106.5	0	103.6	0	105.2	0	128.5		
$R_{s1}$	-1.27	0	-4.60	0	-4.60	0	-1.46		

Figure 2



stants,  $R_{s,1}$  and  $R_{s,2}$ . To be mathematically rigorous, the equations can be put in the forms:

$$I_1 R_{s,1} + V_{g_s} + I_2 R_{s,2} = 0$$

$$\text{and } I_2 R_{s,2} + I_1 R_{s,1} = 0$$

and then the correct signs as determined from field test are used when the constants are placed in the equations.  $V_{g_s}$  is called negative, or exposure, because the earth is negative to the pipe by that magnitude and it is the purpose of the rectifier to change the voltage between pipe and earth by 4 volts in order to eliminate the possibility of corrosion.

An easy method of solution is to solve equations (18 and (19 simultaneously for  $I_1$ :

$$I_1 = \frac{V_{g_s} R_{s,2}}{R_{s,2} R_{s,1} - R_{s,1} R_{s,2}} \quad (20)$$

Substituting the network constants obtained from the data sheets at the end of the article:

$$I_1 = \frac{4 \times .292}{.292 \times .403 - .0894 \times .146}$$

$$= 11.2 \text{ amperes rectifier current required.}$$

Now, solve equation (19 for  $I_2$ :

$$I_2 = \frac{I_1 R_{s,1}}{R_{s,2}} \quad (21)$$

Substituting the network constants and the value for  $I_1$ :

$$I_2 = \frac{11.2 \times .0894}{.292}$$

$$= 3.4 \text{ amperes bond current required.}$$

As explained earlier, the equation for bond resistance is derived by solving the bond current equation:

$$I_2 = \frac{E_2 + I_1 R_{s,1}}{B_2 + R_{s,2}} \quad (22)$$

$$\text{Therefore } B_2 = \frac{E_2 + I_1 R_{s,1}}{I_2} - R_{s,2} \text{ ohms} \quad (23)$$

where  $B_2$  = bond resistance to be connected between pipelines.

Substituting the network constants:

$$B_2 = \frac{3 + 11.2 \times .123}{3.4} - .360$$

$$= .93 \text{ ohms bond resistance.}$$

The final ground voltage change at terminals 3 resulting from the algebraic sum of beneficial effect due to rectifier current and the adverse effect due to bond current, can be determined from the equation:

$$V_{g_s} = I_1 R_{s,1} + I_2 R_{s,2}$$

$$V_{g_s} = 11.2 \times .0824 - 3.4 \times .127$$

$$= .49 \text{ volts.}$$

It will be observed on the field data sheets that ten readings were taken at each location and that the network constants were derived from the averages of the ten readings. This was necessary because stray railway current effects caused the meter pointers to fluctuate continually and thus no single reading could be relied upon for accuracy. Even when stray currents are not present, it is advisable to take several readings at each set-up in order that errors in observation and recording can be discovered.

The mathematical expression for the method used for computing the constants from the field data is:

$$R_{a,b} = \frac{\sum \Delta V_{g_a}}{\sum \Delta I_b}$$

### References

1. J. M. Pearson, Measurements of Cathodic Polarization and Problems of Interference on Underground Structures, National Bureau of Standards Corrosion Conference, 1943.
2. A. V. Smith, Cathodic Protection Interference, American Gas Association Distribution Conference, 1943.
3. J. M. Pearson, Electrical Instruments and Measurements in Solution of Electrolysis Problems, National Bureau of Standards Corrosion Conference, 1937.

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# Cathodic Protection Applied To a Large-Diameter Oil Pipe Line System\*

By D. O. GRIFFITH\*

## Introduction

THE RANCHO Pipe Line System consists of 455 miles of coated 24-inch trunk-line pipe and six terminals or stations (Figure 1). The line originates at McCamey, Texas and terminates at refineries along the Houston Ship Channel. Construction was completed in 1953. The system traverses terrain involving high-resistant dry and low-resistant wet soils, highly congested metropolitan areas and multiple interference problems resulting from cross lines and from parallel lines in a common right-of-way.

## Discussion

Use of prestressed steel, large-diameter, thin-wall pipe and electrically-operated equipment and controls presented many additional considerations in the design of the cathodic protection system. Because the severity of corrosion "notch effect" on prestressed steel was undetermined, it was believed that immediate partial protection would be more desirable than later complete protection, therefore, cathodic protection was designed for earliest possible installation. Operating interruptions caused by corrosion of small control piping in station yards were considered as costly in loss of revenue as trunkline failures. Thus cathodic protection became a problem of initial prevention of corrosion occurrence rather than one of later mitigation or correction of indicated corrosive conditions.

A study of the proposed system by experienced corrosion engineers revealed several factors upon which predesign of the cathodic protection system could be based. Such factors as the following were considered:

1. Experienced personnel would be used for inspection during construction to insure good coating application.
2. Good coatings would allow protecting maximum-length sections of line in congested areas from a remote source that would establish normal protective potentials through these congested areas with currents small enough to prevent damage to adjacent foreign structures.
3. Distributed current systems combined with good coating in congested areas would allow more nearly uniform protection at normal protective potentials, reduce currents, and minimize foreign interference.
4. The current requirements of the pipe to be protected could be reasonably estimated if good coating were assured.
5. Cathodic protection units installed in station yards would result in considerable savings on the initial installation, operating power costs and routine in-

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## Abstract

Cathodic protection of a large-diameter pipe line transporting crude oil from West Texas to refineries located near the Houston Ship Channel presented many problems. The asphalt and coal tar enamel coated line was constructed of thin-wall, prestressed pipe. It traversed terrain with widely-varying characteristics, numerous road and river crossings, intersecting pipe lines and parallel lines in a common right-of-way. Distributed sources of limited current drainage combined with unidirectional bonds were desirable for protection in congested rights-of-way and metropolitan areas in order to minimize adjacent structure interference. Most of the cathodic protection installation was completed by the time the line was placed in operation. Installing protective units in locations convenient to pumping stations permitted cooperative inspection and maintenance by operating personnel. It was estimated that 99.9 per cent of the trunkline piping was effectively insulated. A regular inspection schedule provides records for evaluating the efficiency of the protection and predicting any decline.

pection and maintenance. Inspection of such units, normally made once a month in remote locations, could be made effectively each week in station yards by the operating personnel on duty. If necessary, ground beds could be watered economically at station locations.

## Coating

Approximately 60 percent of the trunkline piping was coated with a 3/32-inch single flood coat of hot applied improved asphalt, reinforced with 20-mil glass mat and covered with 6-pound coal-tar saturated asbestos felt wrapper. The remaining trunkline piping was coated in a similar manner using standard coal tar enamel. Steel conduits and service lines in station areas were galvanized and asphalt rubber mastic was applied cold to damaged areas and couplings. Asphalt enamel having high resistance to cold flow was considered best suited for areas in dry climatic conditions where rough trench was encountered, whereas coal tar enamel was considered more

\*A paper presented at a meeting of South Central Region, National Association of Corrosion Engineers, Dallas, Texas, October 13-15, 1954.

\*Shell Pipe Line Corp., Houston, Texas.

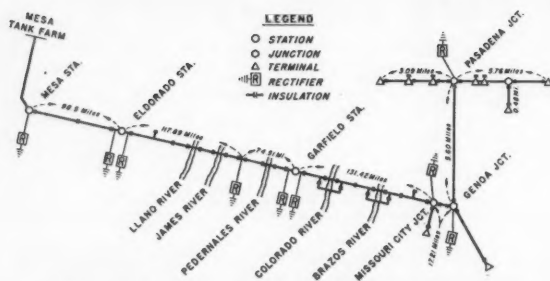


Figure 1—Schematic diagram of Rancho 24-inch pipe line.

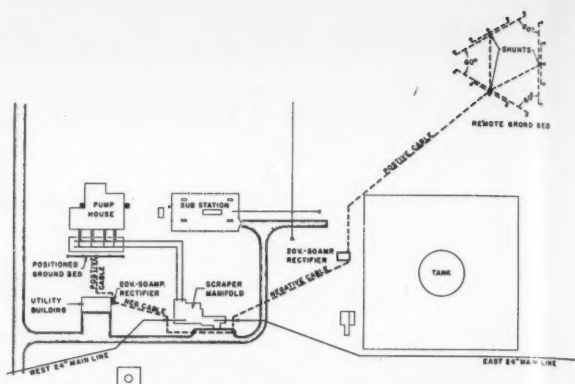


Figure 4—Garfield Station cathodic protection unit.

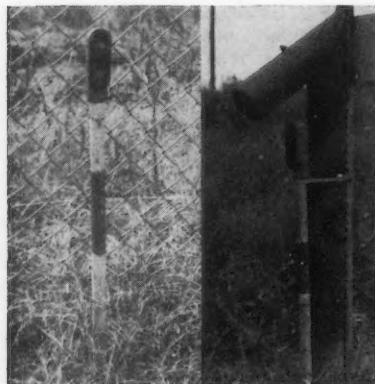


Figure 2—Test leads at insulated joints, 6-inch cast iron line and road casing.

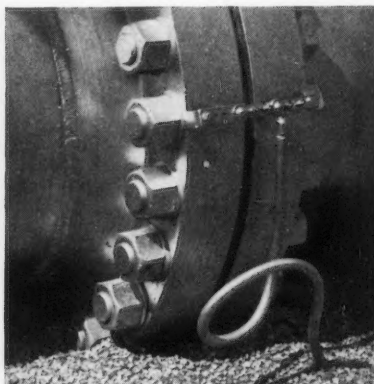


Figure 3—Insulating flanger bondover with shunt.

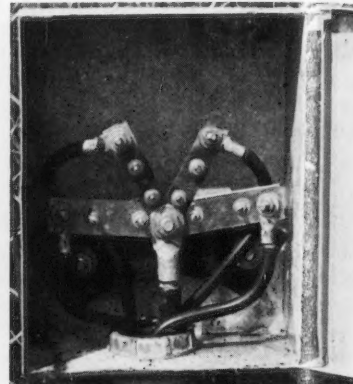


Figure 5—Shunt junction box.

advantageous in wet or contaminated soils. All coating was electrically inspected for voids which were repaired during construction.

Pipe installed in casings was coated with multiple layers of glass mat imbedded in 6/32-inch thick hot enamel to insure insulation of the pipe from the uncoated casing.

#### Test Leads

During line construction test leads consisting of polyethylene insulated No. 8 stranded copper wire attached to the pipe by a powdered thermite welding process were installed at road casings and at intervals not exceeding two miles along the line. These leads were brought above ground in a 30-inch piece of 3/4-inch conduit and connected in a dead-end weatherhead conduit, as shown in Figure 2. Composition blank conduit covers were drilled and provided with a silica bronze bolt, 1/4-inch in diameter and 3/4-inch long, in order to attach the lead wire solder lug to the back of this insulating cover. These threaded bolts extending through the cover were used for test terminals.

#### Insulating Flanges

Insulating flanges were installed to isolate possible trouble sections such as river crossings, etc., to separate line piping from station piping and to separate lines of dissimilar metal composition. One millivolt per ampere shunts with capacity up to 30 amperes

were installed in all insulating flange bondovers to allow testing without altering current distribution or disturbing line polarization (Figure 3).

#### Preliminary Testing

Immediately following backfill operations on the line, natural soil-to-pipe potentials were observed and recorded on line sections. Even though it was realized that current requirements would possibly increase with time, temporary bonds to adjacent cathodically protected lines allowed an additional potential survey to determine protection current requirements. At locations where such current was not available, portable test generators were used in conjunction with temporary ground beds. These consisted of sections of steel pipe one inch in diameter and five feet long, placed in augered 1 1/2-inch holes filled with salt water.

#### Rectifiers

Three-phase, oil-immersed rectifiers were used to supply cathodic protection currents where power was available in such form; otherwise, single-phase units were used. Fifty percent over-design of rectifier capacity was considered desirable to allow for coating deterioration; initial temporary, high-level, long-range protection during construction; and possible increased current demand by future system expansion.

#### Ground Beds

Soil resistivity measurements were recorded at pro-



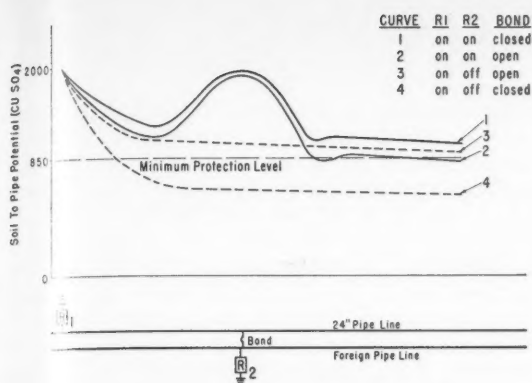


Figure 6—Typical shielding interference.

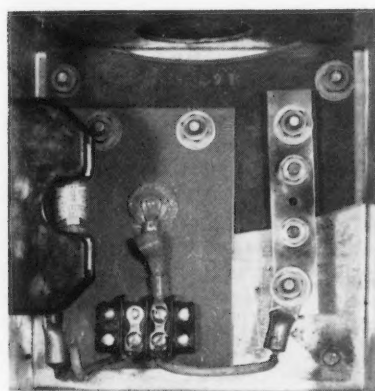


Figure 8—Germanium rectifier.

posed groundbed sites using the four-electrode method with Vibroground. These tests revealed average soil resistance at various depths. Test holes were augured to determine rocky or sandy conditions.

Ground beds were designed for locations either remote from the cathode, allowing low current density transmission across long distances with moderate soil-to-pipe voltages at the line, or close to the cathode in order to focus greater current density on most critical piping (Figure 4). Remote ground beds usually consisted of fifteen graphite rods, 3 inches in diameter and 60 inches long, placed in augured holes 18 to 24 inches in diameter and 15 feet deep and surrounded by pneumatically-tamped soft coal coke breeze. These rods were spaced at distances varying from 25 to 30 feet apart in an equilateral-triangle pattern and connected by No. 6 polyethylene insulated copper cable to aboveground shunt junction boxes which were centrally located on each leg of the bed (Figure 5). Connections between shunt junctions and the rectifier were made with 2/0 cable. All connections were made with copper soldering lugs; underground splices were coated with two inches of hot-applied asphalt. Groundbed installations were made by contracting personnel, and design and inspection were made by employees of Shell Pipe Line

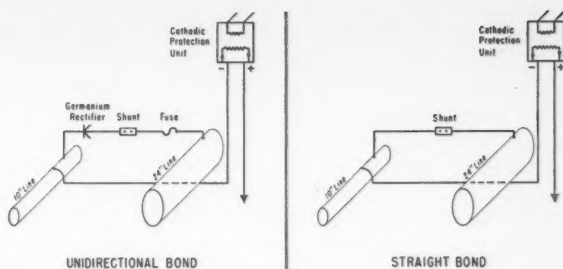


Figure 7

Corporation. Some anode holes had to be cleared with dynamite to utilize low-resistant soils both above and below rock tables. These holes were dynamited, excavated, backfilled with wet dirt and then re-augured. In some instances rods had to be installed in horizontal positions because of rock tables. Where possible, rods were installed at permanent moisture depths.

#### Operational Adjustments

The known cathode which was composed of coated trunkline pipe, buried metal in the station system and affected foreign structures, was analyzed for metallic components such as steel, cast iron, zinc, copper, etc., in order to determine the desirable values of cathodic protection potentials. A study of the electromotive and the practical series, resulted in the use of the following minimum values in measuring soil-to-metal potentials with copper sulfate electrode to determine absolute protection: zinc, 1390 millivolts; iron, 850 millivolts; lead, 810 millivolts; and copper, 520 millivolts. In order to minimize the possible loss of bond through electrolytic breakdown of water that might become entrapped under faulty spots of coating, the potential impressed on coated pipe was limited to 2400 millivolts when possible. Actual measured galvanic solution potentials of zinc ground wells (electrical equipment grounds) and galvanized piping averaged 1140 millivolts. These buried, zinc-coated structures received very little protective current at soil-to-metal values below 1140, whereas at higher values large amounts of current drained from them produced only a small increase in the soil-to-metal potential. This value therefore was considered as the minimum potential criterion on coated lines connected to electrical ground wells at remotely operated valves. By maintaining this potential it was believed that electrical grounding systems would suffer little or no corrosion.

#### Bonding

Bonding to foreign structures was largely a problem of shielded soil potential rather than loss of metal through straying currents. Potential gradients produced in the soil along the line from remote rectifiers usually were blocked at points where the line crossed the potential gradient "node" of foreign-owned rectifier installations which supplied protection to parallel lines in the common right-of-way. In many of these

instances damaging interference currents were immeasurably small because of the relative high-potential, low-current requirements of the 24-inch well-coated trunkline. The only solution to this problem, other than bonding, was the installation of additional rectifiers at locations between each two foreign units, or the application of excessive voltages from existing units which would override potential gradients in the soil produced by the foreign installation (Figure 6).

Germanium rectifiers were used at foreign line bond locations because currents involved were extremely small and different degrees of effective coating on the cathodes (lines) made a unidirectional bond necessary (Figure 7). Unidirectional bonding allowed current to flow from the 24-inch line through a metallic conductor to the offending foreign line, but it blocked a current in the opposite direction that would occur in cases where the foreign cathodic protection units ceased to operate (Figure 8). Germanium rectifier bonding has the advantage, over other types of rectifier bonding, of allowing current flow at very low circuit voltages.

#### *Completed Installation*

Application of cathodic protection to the entire system required nine rectifiers, using 99 impressed current anodes. Total current applied for protection of station piping at six locations was 121.2 amperes. Current used for protection of the 456.40 miles of 24-inch pipe line amounted to 58.3 amperes of which 22.5 amperes was drained from foreign lines through bonds; however, 11.2 amperes was drained to foreign lines through bonds at other locations, resulting in a net total of 47.0 amperes of current required to protect the coated trunkline. These current flow values were recorded after one year of cathodic protection of the line. The maximum soil-to-pipe potential measured with copper-sulfate electrodes was 2400 millivolts, whereas the minimum protective potential recorded was 900 millivolts. On the basis of these recorded readings, 0.3-microampere per square foot of trunkline was required for protection. Considering these calculations to be true, it may be assumed that approximately 99.9 per cent of the trunkline piping was effectively insulated, if two milliamperes per square foot of bare metal is required for protection as reported by numerous corrosion engineers.

#### *Inspection and Records*

The most effective preventive work was considered useless without records. The cathodic protection of this line was regarded as a problem of corrosion prevention rather than one of corrosion mitigation; therefore accurate, plentiful data had to be recorded. Office records with duplicate field copies were set up to include a summary of all work accomplished whereby engineers could evaluate effectiveness and forecast possible failures of protection. These records required regular field inspections of the system which were scheduled as follows:

- 1) complete system check once every four months by an inspector trained in corrosion prevention;

- 2) weekly inspection of units installed at stations by operating personnel; and
- 3) monthly inspection of remotely installed units.

The complete system check includes such work as recording soil potentials at all test leads; measuring current flow at all shunts and IR drop test leads; checking all mechanical connections for tightness and contact at shunt junctions, bonds, rectifiers and insulating flanges; checking the current output of each impressed anode; calibrating meters; and making necessary current adjustments in the cathodic protection system. Monthly and weekly checks performed by operating personnel consist of visual inspections of the apparent operating conditions of rectifiers, bonds, shunt junctions and insulating flanges. Observed meter readings and defects are reported to the Area Corrosion Engineer on routine operating reports submitted over the line communication system to oil dispatching personnel.

#### **Conclusions**

The magnitude of any cathodic protection problem is directly proportional to the size of the cathode exposed to corrosion attack. When considering cathodic protection of a buried pipeline located in a narrow right-of-way which crosses congested industrial areas, it is sometimes impossible economically to protect the line without restricting its current requirements. Many pipelines are laid on 50-foot right-of-way strips, but are protected with currents that may affect ten times that right-of-way width. Improved coating methods and materials and higher coating standards appear to be the only practical solutions to the problem of restricting the cathode sufficiently to allow protection with inoffensive currents that will be confined to the right-of-way.

Cooperative efforts by all participants with pipe lines in a common right-of-way would greatly reduce the amount of damaging currents in the soil, thereby allowing cathodic protection at much lower potential levels. Consideration of all lines in a right-of-way as a single cathode with one cathodic protection system, even though the protection units were separately installed and maintained, would allow replacement of many unstable, costly bonds that were installed to correct an offense, by stable bonds which prevent offenses. Liberal installations of unidirectional rectifier bonds should facilitate equitable current adjustments for all individual lines, provide increased protection of lines having similar cathodes at existing protective potential levels, or allow the present degree of protection at decreased unit outputs which would result in increased efficiency and economy for all companies involved.

#### **Acknowledgment**

The writer thanks the management of Shell Pipe Line Corporation for permission to present this paper and gratefully acknowledges the constructive criticism of Messrs. O. C. Mudd, L. B. Nelson, E. B. Mitchell, L. R. Sheppard and J. T. Bergeron in its preparation.

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# NACE TECHNICAL COMMITTEE REPORTS

Publication 55-2

## A Report of Technical Unit Committee T-1K on Inhibitors for Oil and Gas Wells

### Proposed Standardized Laboratory Procedure For Screening Corrosion Inhibitors For Use in Oil and Gas Wells\*

#### Part 1—Development of a Standardized Laboratory Procedure for Screening Corrosion Inhibitors for Use in Oil and Gas Wells

INHIBITORS came into general usage in the oil and gas producing industry about 1945 and increased in both use and numbers with amazing rapidity in the period 1945-1952. In the latter year it became evident there was a need for some sort of "yard-stick" to measure the relative effectiveness of the myriad of compounds available before putting them to actual field trial. With such a "yardstick" an inhibitor's effectiveness could at least be qualified when compared in the laboratory to other inhibitors that were field proved.

At the 1952 annual National Association of Corrosion Engineers meeting the writers were commissioned by the chairman of TP-1 (now T-1) Committee to conduct a survey of operating companies, manufacturing companies and universities to determine the various methods they used in screening or evaluating compounds to be used as corrosion inhibitors in oil and gas wells.

As a result of this inquiry a paper was given during the 1953 annual NACE meeting presenting the methods used by 11 producing companies, five manufacturing companies and one university. Of the 17 replies only 12 reported in enough detail for evaluation. Of these twelve, 10 companies reported using a system in which a weight loss of some type was measured in a corroding system similar, at least in character, to those found either in sour crude oil or gas condensate wells. The paper presented in 1953 presented data further substantiated the effectiveness of these various types of tests in screening or evaluating inhibitors for field use.

Based upon the recommendations made as a result of the paper's presentation, the chairman of TP-1 (now T-1) established a subcommittee of T-1 now known as Unit Committee T-1K. The initial meeting of T-1K was held in October 1953, and as a result

#### Abstract

The need for a standard laboratory procedure for screening corrosion inhibitors prior to field testing, for use in the oil and gas producing industry, was recognized by TP-1 (now T-1) in 1952. A paper presented at the 1953 NACE annual conference presented various methods of laboratory screening or evaluation being used. T-1K was organized for the purpose of developing a standardized test. As the result of the work of this committee, a standardized test has been devised and tested by various producing company laboratories. The test described in this report is a static oil and water immersion test using the weight loss of a steel coupon when under the influence of an inhibited system compared to its weight loss under an uninhibited system as a criteria of corrosion protection.

of this meeting a program was outlined aimed at the establishment of a NACE recommended standardized test for use in the laboratory to screen inhibitors for use in oil and gas wells (this test hereinafter referred to as proposed standardized test). The opinions expressed at this meeting by both producing and manufacturing companies pointed to the fact that any test, to be considered valid by all concerned, would have to encompass the principle of weight loss of steel in a corroding medium. Such techniques as measuring hydrogen evolution, film resistivity, etc., brought out in the original paper would probably not be acceptable on an industry wide basis for sometime to come. It was decided that the initial effort would be to devise a test for use in sour crude oil systems.

It was further decided at the initial meeting that the best way to attack the problem was to send a number of inhibitors to each of several laboratories for evaluation using their own methods. This was done and at a meeting of T-1K in March, 1954, held during the annual NACE meeting in Kansas City, results of these tests were reviewed. In May, 1954, another meeting of the committee was held and results of these tests, shown in Table 1, were further discussed. It can be seen from these results that there was relatively good agreement in picking the best and worst of the inhibitors. In view of the fact that the comparison between dynamic and static test results was favorable and since simplicity was one of the major prerequisites for a standardized test, it was decided that the initial efforts would be along the lines of a static immersion test.

In the light of the above, at a May, 1954 meeting

\*Presented at a meeting of South Central Region, National Association of Corrosion Engineers, Dallas, Texas, October 12-15, 1954 and prepared for presentation at the Eleventh Annual Conference, National Association of Corrosion Engineers, Chicago, Ill. March 7-11, 1955, by J. C. Spalding, Jr., Sun Oil Co., Dallas, and E. C. Greco, United Gas Corp., Shreveport, La., respectively chairman and vice-chairman of T-1K.



TABLE 1—Relative Position in Value

Laboratory	1	2	3	4	5	6	7		8
Method...	Static Brine	Static Brine	Static Brine & Oil	Dynamic Brine & Oil	Dynamic Brine & Oil	Dynamic Brine & Oil	Dynamic Brine	Avg.	Drop Size Ratio
Inhibitor									
A.....	4	5	2	2	2	4	6	3.6(4)	5
B.....	1	4	3	1	4	3	1	2.4(2)	2/3
C.....	5	3	6	5	3	5	3	4.4(5)	6
D.....	2	2	4	3	5	2	4	3.1(3)	4
E.....	3	1	1	4	1	1	2	1.8(1)	1
F.....	6	6	5	6	6	6	5	5.3(6)	2/3

## AVERAGES

Inhibitor	Static Average	Dynamic Average	Overall Average
A.....	3.6(4)	3.5(3/4)	3.6(4)
B.....	2.6(2/3)	2.2(2)	2.4(2)
C.....	4.6(5)	4.0(5)	4.4(5)
D.....	2.6(2/3)	3.5(3/4)	3.1(3)
E.....	1.6(1)	2.0(1)	1.8(1)
F.....	5.6(6)	5.8(6)	5.3(6)

TABLE 2—Results of Second Series Tests. NACE Committee T-1K

Laboratory.....	1	2	3	4	5	6	7	8	Average	*Theoretical
Inhibitor										
1.....	5	5	5	5	5	5	5	6	5.1(5)	5
2.....	1	1	2	2	2	2	1	2	1.5(1)	1
3.....	2	2	3	1	3	2	2	3	2.3(2/3)	4
4.....	3	3	1	3	1	3	3	1	2.3(2/3)	2
5.....	6	6	6	6	6	6	6	5	5.9(6)	6
6.....	4	4	4	4	4	4	4	4	4	3

\* Based on Chairman's previous impression of inhibitors and alterations made on same.

of the committee a tentative proposed standardized laboratory method was outlined. This method was submitted to the 10 member laboratories along with six inhibitors made up by the writer in varying concentrations, dilutions, etc. Seven laboratories reported the results of the proposed standardized test and the results of these are presented in Table 2. Once again the committee found good correlation among the member laboratories, especially in picking the best and worst inhibitors. With only minor revisions, the test procedures used in obtaining these results are the same as are presented in Part 2 of this report.

Essentially the test is a static oil and water test utilizing the weight loss of a mild steel coupon when under the influence of an inhibited solution compared to an uninhibited solution of a synthetic sour (containing  $H_2S$ ) brine. The test subjects the steel coupon to an inhibited solution of oil, in the case of oil soluble inhibitors, for a short period of time and for the duration of the test the coupon is immersed in brine; of course, in the case of the water soluble inhibitor the brine is inhibited. The equipment as described in the proposed standardized test procedure is relatively simple. A sketch of it is included in Part 2 of this report. It consists of a 1000 ml narrow mouth Erlenmeyer flask, a No. 9 rubber stopper, a small glass hook and a 1 by 1 by 1/16-inch mild cold rolled sheared piece of steel. The equipment is so simple it is unique in a modern laboratory. The preparation for the tests is also relatively simple and almost anyone with one year's laboratory experience should be able to run it satisfactorily. Brine for the test is made up of 5 percent by weight of CP NaCl in distilled water which is scrubbed with

prepurified nitrogen to remove oxygen and then saturated with  $H_2S$  until a concentration of approximately 500 ppm is obtained. The oil used in the test is kerosene filtered to remove contaminants such as polar materials that it may contain. The coupon is prepared by removing mill scale, grinding the surface, removing grease, drying and placing in a desiccator until weighed and used. The coupon is weighed on an analytical balance using a standard laboratory method.

The test procedure is relatively simple in that the inhibitors are tested at a concentration of 10, 25, 50, and 100 ppm based upon the total fluid. The total fluid in the flask consists of 900 ml of the brine previously described and 100 ml of the oil or a total of 1000 ml. First the flask is flooded with prepurified nitrogen and oil is placed in the bottom of the flask. Brine is introduced to the bottom of the flask slowly to avoid splashing. If an oil soluble inhibitor is used the correct amount is dispersed in the kerosene. If a water soluble inhibitor is used, it is added directly to the flask. When the system described above is completed a weighed coupon is suspended on a glass rod in the oil phase for 10 seconds then extended into the brine where it is allowed to remain for seven days. At the end of this time the coupon is removed, electrolytically cleaned or by means of inhibited acid, until free of corrosion product. The coupon is then dried and weighed. All tests are run in duplicate and duplicate controls are run at the time of all tests. Results of the tests are reported as:

- A) **Percent Inhibition** (in which the percentage of protection is calculated by a simple formula) and
- B) **Appearance of Coupon** (in which the surface of the coupon is examined visually using 25 to 100 power magnification and the results of the visual examination reported by a description of the surface in regards to presence or absence and relative severity of pits and/or blisters.)

The foregoing is a brief statement of the test equipment and procedures. It may seem to be ridiculously simple and in actuality it is extremely simple. It is estimated by most people that have run this test that, after the initial equipment is set up, it takes only 13½ minutes to prepare each test, evaluate and record the results. Since there are four concentrations and one control (total 5) to be run in duplicate for each compound to be screened it means that 10 separate tests must be prepared for each compound. This means a total expenditure of time of approximately 2 hours and 15 minutes per compound. It

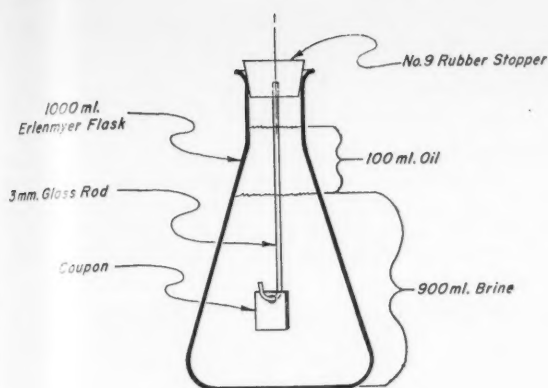


Figure 1—Test flask.

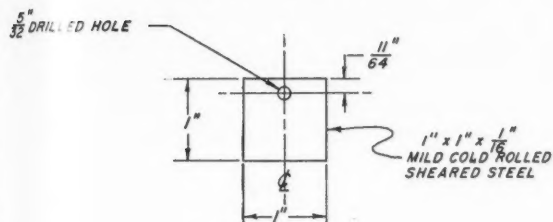


Figure 2—Test coupon.

is doubtful that any other test method proposed to date could be accomplished in such a short length of time. Another highly advantageous point of this procedure is the number of tests that can be run at any given time. This number is limited practically only by available shelf space and the number of Erlenmeyer flask setups. The 7-day period gives ample time for corrosion to take place and fits nicely into the present labor policies of a 5-day week. By working full time on a continuous basis and with enough Erlenmeyer flasks and shelf space it is estimated that eighteen (18) different compounds could be screened every week by one technician.

The committee believes the proposed test answers a dire need in the oil and gas producing industry. Several favorable comments from producers for the adoption of the test and appreciative remarks concerning the adoption of standardized tests from several manufacturing concerns have been expressed already.

#### Part 2—Proposed Standardized Laboratory Procedure for Screening Corrosion Inhibitors for Use in Oil and Gas Wells\*

##### Inhibitors For Use In Sour Crude Wells

###### 1. General

The test as proposed is a static oil and water test utilizing the weight loss of a mild steel coupon when under the influence of an inhibited solution compared to an uninhibited solution of synthetic sour (containing  $H_2S$ ) brine. The test as described below subjects the steel coupon to an inhibited solution of oil, in the case of oil soluble inhibitors, for a short period

of time and for the duration of the test the coupon is immersed in brine.

###### 2. Equipment

Each test container will consist of a 1000 ml narrow mouth Erlenmeyer flask (Corning No. 4980). This flask takes a No. 9 rubber stopper. A  $5\frac{1}{2}$ -inch long 3 mm glass rod with a  $\frac{1}{4}$ -inch radius hook, bent in one end, should be sharpened at the end for insertion into the bottom of the stopper. Figure 1 depicts this set-up.

###### 3. Material

**A. Coupons**—Each coupon shall be a 1 by 1 by  $\frac{1}{16}$ -inch mild cold rolled sheared piece of steel. A  $\frac{5}{32}$ -inch diameter hole shall be drilled (not punched) in this coupon as shown in Figure 2. *Note:* See Section 4 below for preparation.

**B. Brine**—The brine for the tentative proposed test will be made from distilled water with 5 percent (by weight) CP NaCl. It is suggested that the brine be mixed by scrubbing with pre-purified nitrogen passed through medium glass porosity sintered dispersion tube until air free (or until brine does not cloud upon addition of  $H_2S$ ). Hydrogen sulfide ( $H_2S$ ) should then be injected into the brine until a concentration of  $500 \text{ ppm} \pm 100 \text{ ppm}$  is obtained.

**C. Oil**—The oil for the test shall be kerosene filtered as follows: Place one quart Fuller's earth on cotton plug in large glass funnel. Use gravity filtration only. Discard Fuller's earth after 5 gallons of kerosene has been passed through. *Note:* The reason for this filtration is to insure removal of certain contaminants such as polar materials from the kerosene.

###### 4. Surface Preparation of Coupon

- Remove all mill scale.
- If pits are visible, discard.
- Grind with mechanical sander with medium metallurgical paper (240 grit). *Note: Do not touch with fingers after the above step.*
- Buff with soft brush to remove grit.
- Dip in acetone or petroleum ether.
- Place in desiccator until weighed and used.

###### 5. Weighing of Coupon

The coupon shall be weighed prior to beginning test on an analytical balance to  $\frac{1}{10}$  milligram.

###### 6. Test Procedure

###### A. Inhibitor Addition:

- Concentrations—Inhibitors will be tested at a concentration of 10, 25, 50 and 100 ppm based upon the total fluid (900 ml of water plus 100 ml oil equal 1000 ml).
- If a water soluble inhibitor is used, add the correct amount of inhibitor directly to the flask.
- If the inhibitor is oil soluble, disperse the correct amount of inhibitor in the 100 ml of kerosene.

\* Second Revision. Completed October, 1954.

4. Viscous material can be handled easily by using a hypodermic syringe (similar to a Lure Tuberculin syringe, 1 cc graduated in 1/100th ml).

#### B. Procedure

Place oil in bottom of flask. Flood test system (flask) with prepurified nitrogen. Introduce brine, through delivery tube, to bottom of flask slowly to avoid splashing (if brine solution turns cloudy, discard tests). Suspend weighed coupon on glass rod in oil phase for 10 seconds, extend coupon in brine phase, placing stopper in correct position. Leave in this position for duration of test.

#### C. Evaluation of Coupon

At the end of test remove coupon, clean electrolytically or by means of inhibited acid until free of corrosion products. Dry and weigh in accordance with specifications of Section 5.

#### 7. Controls

All tests must be accompanied by controls and the test procedures governing the controls shall be

the same as outlined above with the exception that no inhibitor will be used.

#### 8. Duration

The test must be of 7 days' duration.

#### 9. Number of Tests

Controls will be run in duplicate and duplicate tests will be run at all concentrations. If agreement is not obtained within plus or minus 10 percent or plus or minus 1 mg (whichever is greater), additional checks will be run.

#### 10. Reporting of Results

A. **Percent Inhibition**—Percent inhibition will be reported according to the following formula:

$$100 - \left\{ \frac{\text{wt. loss test coupon}}{\text{wt. loss control coupon}} \right\} \times 100 = \% \text{ protection}$$

B. **Appearance**—Surface shall be examined visually using 25 to 100 power magnification. Results will be reported by description of surface in regards to presence or absence and relative severity of pits and/or blisters.

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# NACE News

## Central New York, Carolinas Sections Organized



AT CAROLINAS SECTION Organizational Meeting—Left to right, H. C. Van Nieuhuys, Southeastern Pipe Line Co., Atlanta, chairman of Southeast Region; Ivy M. Parker, Plantation Pipe Line Co., Atlanta, editor of Corrosion; R. B. Teel, International Nickel Co., Wilmington, N. C., temporary section vice-chairman; E. P. Tait, Alloy Steel Products Co., Inc., Atlanta, regional director of Southeast Region, and R. D. Williams, Fulbright Laboratories, Charlotte, N. C., temporary section chairman.

## Temporary Officers Elected at Charlotte

The organizational meeting of NACE Carolinas Section was held at the Mecklenburg Hotel in Charlotte, N. C. February 4. Twenty-two members attended. H. C. Van Nieuhuys, Southeastern Pipe Line Co., Atlanta, Southeast Region chairman officiated and R. B. Teel, International Nickel Co., Wilmington, N. C. and R. D. Williams, Fulbright Laboratories, Charlotte were organizational meeting chairman and vice chairman.

A polygon formed by Asheville, Augusta, Charleston, Wilmington, Raleigh, Winston-Salem to Asheville including metropolitan areas and suburbs of these cities are boundaries outlined for the section.

Its objectives include promoting meetings for discussion of corrosion problems and presentation of latest developments and ideas on corrosion prevention and control, increasing interest in scientific research for determining corrosion causes and control methods, showing local industry importance of corrosion study and control and encouraging exchange of knowledge and ideas among individuals actively engaged in corrosion work.

Temporary section officers are R. D. Williams, chairman, R. B. Teel, vice chairman and W. C. Burnett, Southern

Bell Telephone and Telegraph Co., secretary-treasurer. Motion was carried by majority of members that temporary officers be nominated for permanent posts and elected at section's first quarterly meeting scheduled April 1. T. P. May, International Nickel Co., N. Y., is to show his company's film "Corrosion In Action" during this meeting.

## Corpus Christi Panel Session to be Repeated

Approximately 55 members and guests at the January 25 meeting of the Corpus Christi Section heard a panel consisting of Carl Dill, Reynolds Metals; Chuck Ward, Magnolia Pipe Line Co.; Ed Kunkle, Celanese Corp.; Hugh Wilbanks, Cathodic Protection Service and John W. Nee, Briner Paint Mfg. Company lead a discussion on subjects brought up by those attending the meeting. It was the consensus that this was one of the most successful meetings held by the Corpus Christi Section and many problems presented the panel were well handled. Due to the success of this meeting the section plans to hold one like it every year.

## Payment of 1954 Membership Dues

In order to avoid interrupted mail and missed copies of CORROSION all NACE members who have not done so already are urged to remit their 1954 MEMBERSHIP DUES before March 31. Association by-laws require that the names of those whose dues are not received by March 31 be dropped from the membership mailing list.

## Andrew Kellogg Named Chairman of New Northeastern Group

Rules and regulations of the newly formed NACE Central New York Section were approved by the Board of Trustees of Northeast Regional Division on January 28. Officers of the section for 1955-56 are Andrew Kellogg, Niagara Mohawk Power Corp., Syracuse, chairman. F. C. Jelen, Solvay Process Division, Allied Chemical and Dye Corp., Syracuse, vice-chairman and John F. Richter, Delrac Corp., Watertown, N. Y. secretary-treasurer.

## Philadelphia Section's 1955 Officers Are Elected

The following officers have been elected to serve as chairman, vice-chairman and secretary-treasurer respectively of the Philadelphia Section for 1955: J. S. Pettibone, American Society for Testing Materials; T. F. Degnan, E. I. du Pont de Nemours and Company and S. F. Spencer, Keystone Shipping Company. Dr. William O. Binder of the Electro Chemical Division of Union Carbide and Carbon Corporation was scheduled to speak on "Corrosion Resistance of Stainless Steels" at the February 11 meeting.



## NACE MEETINGS CALENDAR

### Mar

10 Kanawha Valley Section Topic to be announced. Charleston, West Virginia.

29 Southwestern Ohio Section. Corrosion Resistance of Non-Ferrous Alloys by S. C. Lawson, Ampco Metal, Inc.

### Apr

6 Southern New England Section. Topic to be announced.

6 Niagara Frontier Section. Will cover plastics field.

7 Pittsburgh Section. William J. Ruano, attorney-at-law, will speak on Highlights on Patents and Trade-Marks.

19 Chicago Section. Two movies, "Must it Rust?" by Hot Dip Galvanizers Assn. and "The Big Crossing" on pipe line crossing of Straits of Mackinac are scheduled.

26 Genesee Valley Section. Annual meeting and election of officers.

## San Diego Section Hears Keeling's Discussion

At a dinner-meeting January 19, held by San Diego Section speaker for the evening was Harry Keeling, consulting engineer of Los Angeles. His subject was "Combating Corrosion with Common Sense." It covered practical methods of corrosion protection that can be applied to a variety of cases. In the past, the section had concentrated on one particular type of corrosion prevention at each meeting. Mr. Keeling is one of the pioneers in the corrosion field, starting in the 1920's and was a leader in starting a corrosion prevention program with the Southern Counties Gas Co. He remained with Southern Counties for many years as head of engineering before becoming a private consultant in mechanical and

corrosion engineering. He is past chairman of Western Region NACE and has attended many national meetings. Questions from the floor followed his talk, after which officers for 1955 were announced.

## Harry J. Keeling Is Now Corrosion Consultant

Harry J. Keeling is now engaged in independent corrosion consulting work and no longer employed by Southern Counties Gas Co., Los Angeles as noted in the story on the Fourth Annual Western Regional Division Conference NACE carried in the 1955 January issue of Corrosion. Mr. Keeling's business address is 1718 Livonia Ave., Los Angeles 35.



SENATOROFF



HILL

## Western Region Awards Appreciation Certificates

Certificates of appreciation for outstanding services to Western Region NACE have been given to N. K. Senatoroff, Southern Counties Gas Co. and Preston W. Hill, Signal Oil and Gas Co. The hand-lettered scrolls read in part "This certificate is issued by the Regional Board of Trustees on behalf of the members as a lasting indication of their appreciation." The certificates were presented November 18 during the Fourth Annual Western Regional Division meeting.

Mr. Senatoroff was active in formation of Los Angeles Section and has, among other things, been symposium chairman for the November 1951 Western Region Conference, and chairman and co-chairman of the program committee for meetings in 1954.

Mr. Hill was a member of the Education Committee for the 1952 Western Region Short Course, is active in technical committee work and acts as coordinator between Western Region technical committees and corrosion committees of other societies.

## Southwestern Ohio Section To Approach Management

On January 25, a dinner meeting of the Southwestern Ohio Section was attended by 31 members and guests. After the general business meeting and the reading of the minutes, a letter prepared by Cliff Jones concerning an effort to increase interest and membership in the Southwestern Ohio Section area in the NACE was presented to the membership. Arthur Caster moved that this letter be sent to top management of industry and the motion was seconded and passed. The program was most interesting and well received. This was a panel discussion with Cliff Jones discussing underground corrosion and Sol Gleser discussing underwater corrosion and with Robert Romell acting as Moderator. Much interest was shown in the question and answer period.

## North Central Region Elects New Officers for 1955

It has been announced that new officers for North Central Region for 1955 are as follows: George A. Fisher, chairman, International Nickel Co. Inc., St. Louis; William E. Kleefisch, vice-chairman, Nooter Corporation, St. Louis; Missouri; William J. Ries, secretary, Tretolite Company, St. Louis.

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## Economic Analysis Cited As Aid in Preparing Corrosion Control Projects

Economic analysis can show a corrosion engineer whether or not he is accentuating his most costly refinery corrosion problems according to H. V. Nyland, Sinclair Research Laboratories, Harvey, Ill., in a talk given during the Chicago Section NACE meeting held at the Engineers Club in Chicago on January 15. Approximately 85 members and guests attended.

Speaking on The Application of Economic Analysis to Refinery Corrosion Problems, Dr. Nyland said management is acquainted with application of these analyses to new or improved refinery processes or production of new products. He revealed that corrosion control projects frequently compete with other projects, thus presentation of a corrosion program in this conventional form helps place it in proper relationship. Even though application of economic analysis to corrosion may require somewhat obscure assumptions, predicted earnings from successful corrosion control are nonetheless real, Dr. Nyland pointed out.

A nominating committee was presented for nomination of 1955 officers at the April meeting.

J. S. Long, Devoe & Reynolds Co., Inc., is scheduled to discuss paints and painting at the Section's February meeting.



NYLAND

## Jacksonville Hears Talks on Plastics; Elects Officers

Twenty-nine members and their guests of the Jacksonville Section heard George Hebbard speak on Plastics in Protective Coatings at the January 28 quarterly meeting.

The annual election of officers was also held with the following being named: H. E. Alexander, Dozier and Gay Paint Company, Jacksonville, Florida, chairman; T. W. Bostwick, City of Jacksonville, vice chairman and A. B. Smith, Amercoat Corporation, Jacksonville, Florida, secretary-treasurer.

## Eleven Technical Papers Given at Toronto Course

Eleven technical papers were presented during the first Canadian short course on corrosion held at the University of Toronto, February 2-4. A total of 75 persons representing a cross-section of Canadian industry registered. Course was sponsored jointly by Canadian Region NACE and Southern Ontario Committee on Electrolysis in conjunction with the University of Toronto.

Arrangements were under direction of T. R. B. Watson, Corrosion Service, Ltd., past chairman of NACE Toronto Section. He was assisted by A. H. Carr,

Koppers Products Ltd.; W. H. Dunbar, Bell Telephone Co. of Canada; R. Kuster, The Union Gas Co.; R. J. Law, International Nickel Co. and A. R. Murdison, Imperial Oil Ltd.

Technical papers presented were: Fundamentals of Corrosion by R. B. Hoxeng, United States Steel Corp. Factors Influencing Corrosion Rates by W. F. Graydon, University of Toronto. The Diagnosis of Corrosion Problems and Statistical Tools in Corrosion Work (two papers) by V. V. Kendall, National Tube Division, U. S. Steel Corp.

Corrosion Resisting Properties of Metals and Alloys by W. Z. Friend, International Nickel Co.

Corrosion Due to Imperfections in Alloys by W. C. Winegard, University of Toronto.

Theory of Cathodic Protection by F. E. W. Wetmore, University of Toronto. Practice of Cathodic Protection by T. R. B. Watson.

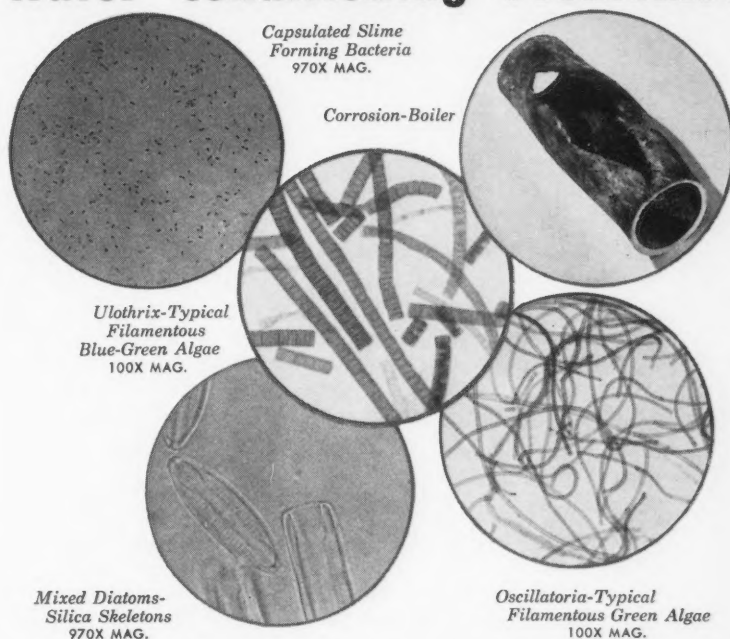
Use of Electrical Instruments in Corrosion Control by A. R. Murdison. Bituminous Coatings by W. F. Fair, Koppers Co., Inc.

Inhibitors by G. R. Connor, Alchem, Ltd.

## Canadian Region Officers

It has been announced that the new officers for the Canadian Regional Division for 1955 are as follows: L. W. Shemilt, University of B. C., Vancouver, B. C., chairman; T. R. B. Watson, Corrosion Services Ltd., Toronto, Ontario, vice-chairman; K. N. Barnard, Defense Research Board of Canada, Dartmouth, N. S., secretary-treasurer.

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## Organic Inhibitors Are Discussed by Panel

Approximately 30 members and guests at the January 27 meeting of the Sabine-Neches Section heard a panel discussion on types of organic inhibitors and actual case histories of inhibitors used in controlling corrosion in process equipment. D. L. Burns of the Gulf Oil Co. acted as moderator for the panel which consisted of W. F. Oxford, Jr., Sun Oil Company; Chris Murray, Pure Oil Co.; Jesse Baker, Magnolia Petroleum Company; Eric Turnbull, Cities Service Refining Corp.

Mr. Oxford discussed general nature of organic inhibitors, various types, comparative costs, means of justification and methods of testing, checking and evaluating inhibitors. Mr. Murray discussed a case history where an inhibitor was used in controlling corrosion and foul-

ing in overhead system on cracked oil fractionating tower and results obtained. Mr. Baker discussed 4 cases where inhibitors were used in his company's plant, method of injection, etc. Mr. Turnbull discussed use of inhibitor in a fractionating tower in an alkylation unit and problems which developed after use of inhibitors began. Mr. Burns discussed inhibitors used in a crude processing unit and various means used to control corrosion.

A question and answer period followed and members of the panel answered questions brought up from the floor. It was announced that F. J. Ploedrl, Wisconsin Protective Coatings Co., Green Bay, Wisconsin, was scheduled to speak on "Catalytically Cured Organic Coatings" at the February 24 meeting.

Of the 95 articles published in Corrosion's Technical Section during 1955 all but 7 were original material.

## Southern New England Section Elects Officers



BARRY



RASMUSSEN



CHAPMAN

F. M. BARRY—Director, Metals Research Dept., Scovill Mfg. Co., Waterbury, is a graduate of Sheffield Scientific School, Yale University with a PhD in chemistry and an MS in metallurgy. He is a member of numerous technical organizations.

L. M. RASMUSSEN—Chemical Engineer, Research Division, Maxwell, Manning & Moore, Inc. He has been actively engaged in corrosion protection since his 1929 graduation from Pratt Institute. His present work is in control of corrosion of valves and instruments.

CHARLES B. CHAPMAN—Hartford Electric Light Co., Hartford, Conn. After graduation from Rensselaer Polytechnic Institute in 1946 with a BS in electrical engineering he was employed by the New York, New Haven & Hartford Railroad.

### F. M. Barry Is Chairman

Frederick M. Barry, Scoville Mfg. Co., Waterbury, Conn. has been elected chairman of Southern New England Section. At the election December 1, L. W. Rasmussen, Manning, Maxwell and Moore, Inc., Stratford and Charles B. Chapman, Hartford Electric Light Co., Hartford were elected vice-chairman and secretary-treasurer respectively.

The business meeting was preceded by a tour of the Southern New England Telephone Exchange in New Haven; a dinner and an after dinner meeting at the auditorium of Southern New England Telephone Company, New Haven.

Technical speaker was James F. Madigan, in charge of the Corrosion Laboratory, Research Dept., Rohm & Haas Co., Philadelphia. He also worked on corrosion problems with Sperry Gyroscope Co. and Moraine Products Div., General Motors Corp., Dayton. His talk covered the fundamentals of corrosion of metals, solution of metals, role of oxygen, basic significance of corrosion products environmental factors and in relation to electrochemical dissolution.

A. W. Tracy, American Brass Company, Bridgeport presided over a ques-

(Continued on Page 67)

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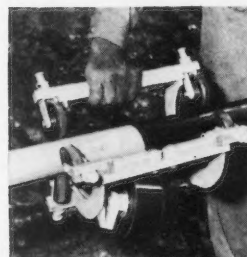
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PLANNING THE MAY NORTHEAST REGION MEETING are, left to right, standing: Arthur W. Tracy, Past Chairman Southern New England Section; John Klim, vice-chairman Schenectady-Albany-Troy Section; Fred Meyers, Southern New England Section; F. J. LeFebvre, chairman Metropolitan New York Section; Andrew Kellog, chairman Central New York Section; Byron Godshall, chairman Lehigh Valley Section; Thomas Degnan, vice-chairman Philadelphia Section; seated: Frank Costanzo, vice-chairman; James Shields, secretary-treasurer; Edward G. Brink, chairman; George E. Best, director and Kempton H. Roll, past-chairman all of the Northeast Region.

More than 1700 abstracts of technical material published in the world's technical periodicals or books were printed in the 1954 Corrosion Abstract Section.

More than 5000 copies of Corrosion published during 1954 were mailed from Central Office NACE. These were in addition to the regular monthly mailings of the magazine.

## Northeast Region Sets Spring Meeting May 9-11

Practical Corrosion Problems and Their Practical Solutions was selected as theme of the Spring Northeast Regional Corrosion Conference during a meeting of the Northeast Regional Board of Trustees held at the Yale Club in New York January 28.

Co-sponsored by the Metropolitan New York Section and Northeast Region, the conference is scheduled at the Statler Hotel in New York, May 9-11. F. J. LeFebvre, Electro Rust-Proofing Co. and Frank E. Kuhlman, Consolidated Edison Co. of New York, Inc., are chairman and vice-chairman. Attendance will be open to anyone interested in corrosion prevention.

Technical committee meetings will be held the first day. Fundamentals of Corrosion, Aboveground Corrosion, Marine Corrosion and Underground Corrosion are subjects of symposia to be held on second and third days of conference.

## ASHACE to Meet

The Semi-Annual Meeting of the American Society of Heating and Air-Conditioning Engineers is scheduled in San Francisco, June 27-29.

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## Design Against Corrosion Discussed by S. J. Long At Chicago Section Meeting

"Predetermined Design Against Corrosion," is the scheduled topic of Dr. S. J. Long, Chemical Director of Devoe & Reynolds Co. before Chicago Section February 15. The dinner meeting includes a report of the nominating committee for new section officers.

Dr. Long's subject includes factors influencing electro-chemical mechanism of corrosion, particularly in the protective coatings held. Design of epoxy type coatings for chemical plants, soap plants and steel mills is among the topics scheduled.

The next meeting of the section to be held in April, will feature showing of the motion pictures "Must It Rust?" and "Big Crossing."

## Ammonia Inhibition Is Discussed at Fort Worth

Walter F. Rogers, Gulf Oil Corp., Houston, spoke on The Effect of Ammonia on Hydrogen Sulfide Corrosion during the February 7 meeting of NACE North Texas Section held at the Cattleman's Restaurant in Ft. Worth. Fifty-four members and guests attended.



ROGERS

Mr. Rogers discussed some factors which cause high hydrogen sulfide corrosion rates under oil field and oil storage conditions as well as field results using anhydrous ammonia as corrosion inhibiting agent.

Section meetings for March and April have been changed to the following:  
March 14—Non-destructive Methods of Testing Metals by George L. C. Dehn, Magnaflux Corp., Dallas.  
April 5—Secondary Recovery by H. L. Bilhartz, Production Profits, Inc., Dallas.

## Alamo Section Meets

On February 15, 1955, at the Alamo Section meeting in the Milam Building, Messrs William A. Howerton, City Public Service Board, M. F. Schlather, United Gas Pipe Line Company and L. J. Cameron, San Antonio Housing Authority were scheduled to speak on "Corrosion and Corrosion Mitigation in San Antonio."

## F. M. Barry Is—

(Continued From Page 64)

tion and answer session after Mr. Madigan's talk.

Frederick R. Meyer, Plant Analyst-Corrosion Protection, Southern New England Telephone Co. and past chairman of the Southern New England Section, addressed the section's February 2 meeting at the University of Bridgeport. His talk included an introduction to corrosion and a discussion of fundamental electrochemical reactions.

New officers were installed at the February 2 meeting.



### on-the-job PROOF!

Test patch of Phenoline 300 at passenger car wash station of a large Eastern Railroad. Patch was subjected to continual spillage of acid cleaning compound (sulphuric) and extremes of weathering. Material applied as 2 coats with total thickness of  $\frac{1}{8}$  inch. After 1 year of service, almost  $\frac{1}{2}$  inch of unprotected concrete had corroded away. Phenoline-protected concrete remained unaffected with bond of Phenoline to concrete still perfect.

## PHENOLINE 300 protects concrete... under severe corrosive conditions

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## LeFebvre Is Installed

### As N.Y. Section Chairman

F. J. LeFebvre, Electro Rust-Proofing Corp., Newark, was installed as chairman; F. E. Kuhlman, Consolidated Edison Co. of New York, Inc., New York City, as vice-chairman, and R. H. Lucke, Esso Standard Oil Co., Linden, N. J., as secretary-treasurer of NACE Metropolitan Section during its January 26 meeting at the Chemists' Club in New York City. Sixty-five members and guests attended.

S. W. Shepard, Chemical Construction Corp., Linden, spoke on Materials of Construction for Process Industries. He related methods of recording and checking corrosion rates and introduced a key-sort file for easy access to this type information. Mr. Shepard also described non-destructive methods for testing critical sections of equipment, including Audinage equipment.

### Manuscripts Scheduled for Publication Listed

The following manuscripts are scheduled to be published in the April issue of Corrosion:

Current Requirements for the Cathodic Protection of Pipe Lines by Marshall E. Parker.

Cell Potentials and Currents by Robert E. Pope.

Electrolytic Descaling — An Electrical Method of Rust Removal from Tanker Ship Compartments by F. E. Cook, Herman S. Preiser and J. F. Mills.

Case Histories of the Failure of Marine Boiler Tubes by Stress Corrosion Cracking by R. D. Barer.

Some Corrosion Inhibitors—A Reference List. NACE Technical Committee T-3A Report.

Corrosion by Valve Packing by L. M. Rasmussen.

The following papers have been approved for publication:

Theory and Research Methods of Metallic Corrosion by G. W. Akimov.

On the Passivity of Iron by Karl Freidrich Bonhoeffer.

Corrosion Studies of a Model Rotary Air-Preheater by G. G. Thurlow.

Internal Plastic Coating of Pipe Lines in Place by J. C. Watts.

Economic Considerations in Pipe Line Corrosion by L. G. Sharpe.

Preliminary Evaluation of Protective Coating Systems by R. W. Flournoy.

### SHORT COURSE CALENDAR

April 5-7 University of Oklahoma. Second Annual Corrosion Control Short Course, Norman, Okla.

April—University of British Columbia, Vancouver.

Fall—Washington University, St. Louis, Missouri.

### 187 Are Registered—

(Continued From Page 68)

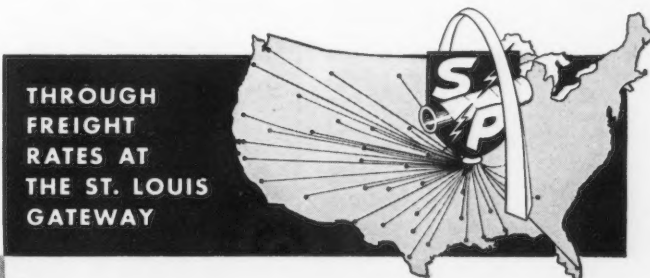
Parker, Cormit Engineering Co.; R. A. Brannon, Humble Pipe Line Co.; O. W. Wade, Transcontinental Gas Pipe Line Co.; M. Frank, Tennessee Gas Transmission Co.; L. R. Sheppard, Shell Pipe Line Corp.; J. A. Hollaway, Houston Pipe Line Co.; W. A. Wood, Jr. and C. L. Woody.

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### Cathodic Protection and Pipe Lines

Mitigation of Corrosion on City Gas Distribution Systems by A. D. Simpson, Jr. .50  
Final Report—Effect of Exposure to Soils on the Properties of Asbestos-Cement Pipe by Melvin Romanoff and Irving A. Denison .50

### Paints and Coatings

Gasoline Resistant Tank Coatings by W. W. Cranmer .50  
Tests, Properties of Corrosion Preventive Lubricants for Lead Sheathed Cables in Underground Ducts—A Discussion by Howard S. Phelps and Frank Kahn .50

### Petroleum Production & Storage

Corrosion in Condensate and in High Pressure Sweet Oil Wells by R. C. Buchan .50

A Promising Spray-Applied Inhibitor of Internal Corrosion of Oil Ship Tanks by J. D. Sudbury, D. A. Shock and F. W. Mann .50

Symposium on Internal Corrosion of Tankers, Part 3—Corrosion Control in Practice by A. B. Kurz .50

Bacterial Corrosion of Offshore Structures by J. A. Caldwell and M. L. Lytle .50

Corrosion Control in Gas Lift Wells, II Evaluation of Inhibitors, By D. A. Shock and J. D. Sudbury .50

Internal Corrosion in Domestic Fuel Oil Tanks by R. Wieland and R. S. Treseder .50

### Economics

The Cost of Corrosion to the United States by H. H. Uhlig .50  
Relation of Corrosion to Business Costs by Aaron Wachter .50

### Inhibitors

Prevention of Corrosion in Cooling Water by R. C. Uimer and J. W. Wood .50  
Dicyclohexylammonium Nitrite, a Volatile Corrosion Inhibitor for Corrosion Preventive Packaging by A. Wachter, T. Skei and N. Stillman .50

### Miscellaneous

Resistance of Aluminum Alloys to Weathering by C. J. Walton, D. O. Spawls and J. A. Nock, Jr., and Resistance of Aluminum Alloys to Contaminated Atmospheres by W. W. Binger, R. H. Wagner and R. H. Brown .50

Interpretation and Significance of Potentials of Metals in Aqueous Solutions by Morris Cohen .50

Effect of Heat Treatment and Related Factors on the Corrosion Resistance and Mechanical Properties of the Straight-Chromium Stainless Steels by F. K. Bloom .50

Statistics—A Useful Tool for the Examination of Corrosion Data by Chas. F. Lewis .50

Laboratory Studies on the Pitting of Aluminum in Aggressive Waters by T. W. Wright and Hugh P. Godard .50

Causes of Corrosion in Airplanes and Methods of Prevention by N. H. Simpson .50

Salt Spray Testing Bibliography by Lorraine Voigt .50

Why Metals Corrode by H. H. Uhlig .50  
Corrosion Control by Magic—It's Wonderful by H. H. Uhlig .50

## Eleventh Annual NACE Conference Will Open at Palmer House for 7-Day Sessions March 7

### Need to Consider Paint Problems in Plant Design Stage Stressed by Eads

W. J. Eads, technical director of Products Research Service, Inc., New Orleans, spoke on Surface Coatings in the Design of Process Plants and Steel Structures during the February 8 meeting of the NACE Houston Section. Approximately 100 corrosion engineers attended. Chemical plants in the Houston area were particularly well represented.

Mr. Eads suggested that a corrosion engineer be on the design team for plants for the purpose of investigating and recommending an initial comprehensive plan for maximum use of protective coatings and that important corrosion problems be considered at blueprint stage. Evaluation of paint systems, surface preparation and application and a good maintenance program were stressed also. Mr. Eads pointed out need for complete studies and understanding of terminology because few terms used in protective coating industry are precise and gave as example the term "coat" or "paint" which he said mean many different things to different people.

### Corrosion in High Pressure Processing Is in Agenda

Corrosion and Embrittlement of Metals for High Pressure Processing is one of the subjects to be presented during the technical sessions of the American Society for Metals at the Ninth Western Metal Congress scheduled at the Ambassador Hotel in Los Angeles, March 28-April 1. Admission to congress sessions is free.

The Eleventh Annual Conference and Exhibition of the National Association of Corrosion Engineers opens in Chicago's Palmer House March 7 and continues through Friday, March 11. The usual extensive program of technical papers has been prepared.

Featured events for this conference are the numerous meetings of the association's technical committees. Many developments of importance in corrosion technology are expected to develop from these meetings.

Customarily there will be the annual banquet, presentation of the NACE Whitney and Speller Awards and of the Junior Award and a program of entertainment for ladies visiting Chicago with registrants for the conference.

All meetings as well as the exhibition, composed of the products of more than 84 firms, will be in the Palmer House.

### 84 Firms Have Space In Annual Exhibition

Contracts for space in the Eleventh Annual NACE Exhibition were signed by 84 firms through February 10. The following exhibitors signed contracts since the report published in February Corrosion:

Cameron Iron Works  
Cathodic Equipment Company  
Rio Engineering Company  
Vacu-Blast Company, Incorporated  
Armour & Company, Chemical Division  
M. J. Crose Manufacturing Company  
Naugatuck Chemical Division of U. S. Rubber Company  
Phelps Dodge Copper Products Corporation

A five-year index to Corrosion's Technical Section was published in December, 1950.

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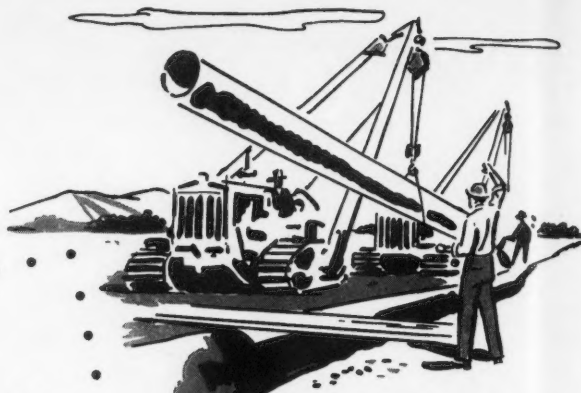
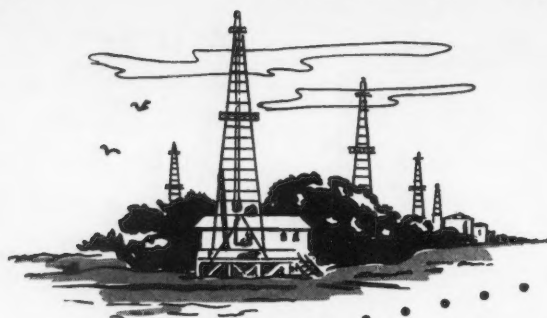
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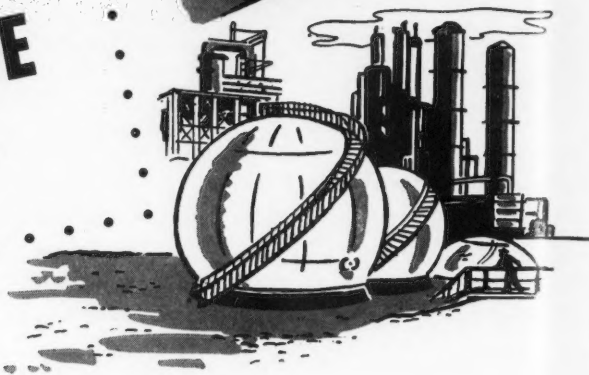
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## Technical Committee News

### 20 Plants Will Cooperate in Cooling Water Tests

#### New Orleans-Baton Rouge Study Group Is Formed

The New Orleans-Baton Rouge section of NACE has organized a local technical study group to study the problems of cathodic protection on offshore oil production equipment. First meeting of the study group was held January 24 at which time topics discussed ranged from the amount of current drainage required to establish effective cathodic protection of the portion of the offshore structures below water to the problems involved in the economic application of protective coatings to those portions of the structure above water. There also was discussion on the potential problems facing offshore operators in inhibiting downhole tubing corrosion of offshore wells.

In order to give the study group the benefit of available knowledge on current and past practices offshore, a questionnaire will be prepared and circulated.

#### Wade Is Vice-Chairman Of Pipe Wrappings Unit

O. W. Wade, senior corrosion engineer, Transcontinental Gas Corp., Houston, has been elected vice chairman of NACE Unit Committee T-2J on Pipe Wrapping Materials. Mr. Wade's first pipeline work was with the White Eagle Division of Socony-Vacuum Oil Company in 1936. He became interested in corrosion work while employed as test engineer for Pratt & Whitney Aircraft Company in 1943.

In 1945 he became division corrosion engineer for Great Lakes Pipe Line Co., joining Transcontinental in 1950. A member of NACE since 1948, Mr. Wade also is active in Unit Committee T-2D on Standardization of Procedures for Measuring Pipe Coating Leakage Conductance, T-3D on Instruments for Measuring Corrosion and Task Group T-3D-1 on Electrical Holiday Inspection of Coatings.

#### X-Ray Diffraction Data

Compilation of data on composition of corrosion products for distribution to committee members is being done by Unit Committee T-3B on Identification of Corrosion Products. Committee has forwarded X-Ray diffraction data for approximately 30 corrosion products to the American Society for Testing Materials card index.

#### Payment of 1954 Membership Dues

In order to avoid interrupted mail and missed copies of CORROSION all NACE members who have not done so already are urged to remit their 1954 MEMBERSHIP DUES before March 31. Association by-laws require that the names of those whose dues are not received by March 31 be dropped from the membership mailing list.

#### A. C. Hamstead Is Head of Of Committee T-5A

A. C. Hamstead of the Carbide & Carbon Chemicals Company, South Charleston, West Virginia, has been elected vice-chairman of Unit Committee T-5A — Chemical Manufacturing Industry. Mr. Hamstead graduated at West Virginia University in 1930 with a BS in chemistry. He has been employed at the South Charleston plant of Carbide & Carbon Chemicals Company since his graduation. He has been actively engaged in corrosion control work for the past 20 years. He is a member of ACS, ASM and NACE.



HAMSTEAD

#### Railroads Are Queried on De-Icing Inhibitor Use

Circulation of a questionnaire to determine experience of railroads using inhibitors in de-icing compounds for platforms and to establish effect of these on rug dyes is scheduled by Unit Committee T-3E on Railroads. Committee is acting as clearing house of corrosion information pertinent to railroads principally through the medium of its Railroad Corrosion News Letter.

A report titled Suggested Procedures for Preparing Tank Car Interiors for Lining is to be published by Task Group T-3E-1 on Corrosion of Railroad Tank Cars. Group is working on procedures for cleaning lined tanks.

First tests of use of magnesium anodes on railroad hopper cars have been encouraging and Task Group T-3E-2 on Corrosion in Railroad Hopper Cars is to continue these tests.

#### More Complete Data Sought On Plastic Materials

A questionnaire on Plastic Materials of Construction along with a generic list of plastics and a list of plastics trade names has been circulated to members and contributing companies by Unit Committee T-5D on Plastic Materials of Construction.

#### Seven Alloy Materials To Be Exposed in T-5C-1 Investigation

Design of corrosion test specimens and racks for investigation of stress corrosion cracking in Gulf Coast cooling waters has been accomplished by Task Group T-5C-1 South Central Region, Corrosion by Cooling Waters. Twenty plants are expected to cooperate in testing of seven alloy materials in brackish cooling waters. The committee is organized into five groups studying recirculating cooling water, once-through cooling water, stress cracking of alloys, testing and inspection procedures and cooling water problems which may not be generally recognized.

Considerable data on cooling water treatment practices and water analysis has been obtained by the Recirculating Cooling Water committee which is currently correcting them. A tentative report on present water treatment practices in once-through cooling systems has been issued to committee members by the Once-Through Cooling Water Committee, which is studying effectiveness of various materials of construction in this practice.

Tentative recommendations on laboratory and plant corrosion testing procedures for possible adoption by member companies for easier comparison of plant to plant test data has been issued by the Testing and Inspection committee.

Recently organized Alloy Stress Cracking committee is obtaining test specimens.

The Task Group has scheduled two meetings in 1955. During 1954 it held a closed meeting in May and an open meeting in conjunction with the South Central Region meeting in Dallas in October.

#### Friend Elected by T-5B

Wayne Z. Friend of the International Nickel Company, Inc., New York, New York has been elected vice-chairman of Unit Committee T-5B on High Temperature Corrosion. Mr. Friend has long been active in NACE and has participated in many of its technical committee activities.

T-5B has submitted a report on Materials for Use at High Temperature to the chairman of Group Committee T-5. It is expected the report will be submitted for publication soon.

#### Inhibitor Mechanism

Mechanism of inhibitor action is scheduled for consideration by Unit Committee T-3A on Corrosion Inhibitors. Committee has published a list of corrosion inhibitors and is awaiting public reaction before planning further work on such listings. In order to keep published information up to date, committee is being formed into task groups for intensive study of inhibitor classes.

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## New Committee Formed on Plastic Film Requirements

Definition of certain minimum requirements of film formulation and application is the major objective of newly organized Unit Committee T-2K on Prefabricated Plastic Film for Application to Pipe Lines. R. B. Bender, Plastic Engineering & Sales Corp., Ft. Worth, organized the committee and is the chairman.

Specific objectives of the committee are to study bonding agents or adhesives, prefabricated plastic films presently available and as discovered in the laboratory, proper applications of both pressure sensitive and prefabricated films to pipelines and preparation of history of experience and results obtained from use of prefabricated films.

## Poor Construction Practices On Water Pipes Discussed

Discussion on external corrosion problems on water service pipes caused by poor construction practices was held during the meeting of Unit Committee T-4F on Material Selection for Corrosion Mitigation November 8 in Los Angeles in connection with the NACE Western Regional Conference.

Galvanic action caused by use of dissimilar metals in valves and fittings in water works piping and selection of corrosion resistant alloys has been primary concern of the committee. It has organized a task group to investigate corrosion in water meters. R. W. Henke, chief mechanical engineer of Badger Meter Manufacturing Co., Milwaukee, will head the group.

## Two Local Committees Are Formed in Chicago

A local technical committee on coatings and one on cathodic protection of underground structures have been formed by the Chicago Section NACE.

The coating committee called the Chicago Local Coatings Group scheduled its first regular discussion meeting at the Chicago Engineers Club, February 8. Louis Zadra, General American Transportation Corp., is chairman.

Work on a project to completely map all existing underground structures in the Chicago suburban area is planned by the local cathodic protection committee. Laurie E. Nichols, Public Service Company of Northern Illinois, is temporary chairman.

## Oil String Casing Groups Schedule Feb. 15 Meeting

A one-day joint meeting of Task Group T-1H-1 on Oil String Casing Corrosion in the West Texas-New Mexico Area and T-1D on Sour Oil Well Corrosion was scheduled for Tuesday, February 15. The purpose of the meeting was to discuss the findings and conclusions of the recent West Texas casing corrosion survey, and to exchange general information regarding sour oil well corrosion in this area.

## Two More Groups Readied by Cable Sheath Groups

"Pipe-type Cable Corrosion Protection Practices in the Utilities Industry" compiled by Task Group T-4B-4 on Protection of Pipe-type Cables and Tests and "Surveys of Lead Sheath Cables in the Utilities Industry" compiled by Task Group T-4B-3 on Tests and Surveys are titles of two interim reports of Unit Committee T-4B on Corrosion of Cable Sheaths. "Stray Current Electrolysis of Lead Sheath Cables in the Utilities Industry," to be compiled by Task Group T-4B-6 on Stray Current Electrolysis and "Cathodic Protection of Cable Sheaths in the Utilities Industry," to be compiled by Task Group T-4B-2 on Cathodic Protection of Cable Sheaths are scheduled for completion in 1955.

## Engineering Design Task Group on Plastics Meets

Assignments of responsibility and general discussion of problems were main topics of the meeting of the Engineering Design Task Group of Unit Committee T-5D on Plastic Materials of Construction held in St. Louis on January 10.

Scope of the Task Group is to review, screen, compile and edit information received by T-5D relative to engineering design and physical properties data of various plastics used as materials of construction. Otto H. Fenner, Monsanto Chemical Co., is chairman.

## Langelier Index Review Planned by Unit T-4E

A review of the Langelier Index and promotion of treatment of municipal and industrial waters for prevention of corrosion are planned by Unit Committee T-4E on Analysis of Domestic Waters. Preliminary results of committees' study of seasonal variation of analyses of six typical municipal waters of the United States with view of finding correlation between corrosivity and chemical analysis are scheduled at its meetings during the 1955 NACE Annual Conference in Chicago.

## Battelle's Cobalt 60 Source To Be Ready for Contract Studies About February 15

A study of radiation effects on electronic components, lubricants and engineering construction materials is included in plans for use of the cobalt-60 source being installed at the Battelle Memorial Institute, Columbus. Housing for the installation has planned capacity of 10,000 curies of the cobalt, however, initial source will consist of 2,000 curies equivalent to \$24 million worth of radium and is scheduled to be generally available to industry for contract studies about February 15.

Source is also expected to aid in furthering progress on radiation sterilization of certain foods, drugs and medical supplies which are difficult, too costly or impossible to sterilize by conventional methods, the institute says.

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# General News

## Organization and Functioning of Corrosion Committees Outlined

### European Corrosion Union Is Organized

Urgent necessity for a European Union of Corrosion was recognized by members of scientific and technical organizations present during a meeting of plastic material chemists and Society of Industrial Chemists held in Paris, France last December.

The union is in effect an association for exchange of ideas on corrosion. It is to function without regard to national boundaries and have liaison with other associations and technical branches. An editorial review board has been designated which is to be composed of representatives of the several countries and groups belonging to the union.

Presently included are scientific and technical organizations, institutions of research, trade associations and individuals located in Belgium, France, Germany, Great Britain, The Low Countries, Scandinavian countries and Switzerland.

### Oklahoma U. Short Course Program Outlined

The April 5-7 University of Oklahoma and Central Oklahoma Section NACE Corrosion Control Short Course will be held at the university Extension Study Center, Norman.

A tentative program has been released as follows:

#### Tuesday, April 5

- 8:9 am—Registration.
- 9:15 am—Ewelcome, W. H. Carson, Dean of Engineering, University of Oklahoma.
- 9:20-10 am—History of National Association of Corrosion Engineers by J. E. Loeffler—John W. Nee, Briner Paint Mfg. Co., will present.
- 10:20-11 am—Physico Chemical Factors of Corrosion by Colby D. Hall, Jr., Dowell, Inc.
- 11:10-11:50 am—Theory of Inhibitors by A. M. Roebuck, Continental Oil Co.

#### Petroleum Production Session

- 1-1:40 pm—Application of Inhibitors by J. B. Robinson, Tretolite Co.
- 1:55-2:35 pm—Casing Corrosion in the Petroleum Industry by Jack L. Battle, Humble Oil & Ref. Co.
- 3:10-3:50 pm—Asbestos cement products.

- 4-4:40 pm—Corrosion Inhibition and Bacteriological Control by W. J. Ries, Tretolite Co.

#### Public Utilities Session

- 1-1:40 pm—Measurement of Earth Potential Gradient by Dan R. Werner, American Telephone & Telegraph Co. Long Lines Dept.

(Continued on Page 77)

### Stainless Equipment Is Needed to Dye New Synthetic Fibers

Use of stainless steels in place of wood and nonferrous construction materials is a basic step in the solution of problems encountered in dyeing synthetic fibers such as nylon, dacron, orlon, vicara, dynel and saran.

Stainless steels eliminate need for duplicate dyeing setups for use with different colors because equipment can be cleaned completely after each bath is run. They offer greater structural strength than wood or nonferrous materials and provide necessary strength to hold heavy loads of wet skeins in the dye cage. Also, availability of one-piece construction offers advantage over assembled construction in that there are no crevices or traps for old dye liquor.

Higher processing temperatures are required for dyeing synthetic fibers than for natural fibers and solutions contain greater concentrations of acids and in general are more corrosive to surrounding equipment.

Wood roughens or splinters when subjected to corrosive dyeing liquids and thus catches or snags fabrics. Also, wood absorbs dye colors and makes it difficult to reproduce precisely the same shade in each batch.

Use of nonferrous materials was not much better because copper pick-up was a source of contamination of the dyeing liquids and this plus other corrosion products in the solutions prevented reproducible colors or color fastness.

Austenitic or "18-8" chromium-nickel types frequently are chosen from a group of cast stainless alloys offering a wide range of corrosion resistant properties because of their strength, ductility and good fabricating qualities. Of these, four alloys, CF-8, CF-8M, CF-8C and CN-7M are principally used in textile dyeing applications. CF-8M grade alloy (containing 2.0-3.0 percent molybdenum) for dyeing machine construction is being used experimentally to determine satisfactory performance.

### Nuclear Congress Set for Cleveland in December

A Nuclear Congress and Atomic Exposition is scheduled in Cleveland, December 12-17. Basic objective of the congress is to launch a continuing program of interchange of information on developing applications of nuclear science for vital national benefits involving industry, agriculture, medicine and public welfare. Participation is open to all major technical groups having an interest in nuclear engineering in any form.

THE TERM "Corrosion Committee" is being used now in place of "Electrolysis Committee conforming to the definitions of terms used by NACE Unit Committee T-4B-3 on Tests and Surveys.

The Bell System recognizes the fact that corrosion committees are organizations through which damaging effects of all forms of corrosion may be mitigated cooperatively and has participated actively in them.

The Detroit Committee has a well-defined organization to handle each problem after it is presented to the standing technical committee. This committee hears the problem, determines the companies involved and arranges time and place for the testing program. After determining from members that the condition has been coordinated, the case is closed at a later meeting. This procedure has permitted most cases to be closed without obtaining additional guidance from the general committee.

#### Systems on Other's Plant

Use of rectifiers and associated ground beds on the plant of other members provides the area of most concern to the Detroit Committee at the present time. A special committee has been appointed by the general committee to clarify mitigative measures and to determine, if possible, what rigid limits, if any, can be placed on the structure-to-earth potentials and amount of interference current picked up by foreign structures.

Determination of whether or not a more serious problem is initiated on a gas distribution system by the mitigation of a water problem is the crux of one of the committee's problems. The member gas company has felt it necessary to hire a consulting firm to determine what corrosion damage they may expect from a rectifier installation. In another case, a non-member company placed a water line directly over the ground bed of a member pipe line company.

#### Function As Technical Committees

The committees in Cleveland, Columbus, Toledo and Youngstown are organized under by-laws which are similar in nature. They function as technical committees and constitute a clearing house for the exchange of engineering information on corrosion problems arising in their respective territories. All arrangements for joint tests or remedial measures are made by direct negotiation among the member organizations concerned.

The Cleveland Committee is attempting to coordinate work of isolating negative return of the street railway system with the Cleveland Transit Company. Although measurable progress has been made in the outlying metropolitan area, continued expected progress has been hampered apparently by lower revenue

(Continued on Page 76)



# Federal Law Aims to Stop Pollution of Interstate Waters

## Powers Given to Surgeon General to Aid Local Agencies

Action by Federal Government to abate pollution of interstate waters is defined in Public Law 845 entitled "Water Pollution Control Act" passed during the 2nd Session, 80th Congress and extended to June 30, 1956 by PL 579, 2nd Session, 82nd Congress. Responsibility and authority relating to water pollution control considered by the law is delegated to the Surgeon General of the Public Health Service (under supervision and direction of the Federal Security Administrator) and to the Federal Works Administrator.

Section 2, (e)(1) of the law reads: "The pollution of interstate waters in or adjacent to any State or States (whether the matter causing or contributing to such pollution is discharged directly into such waters or reaches into a tributary of such waters), which endangers the health or welfare of persons in a state other than that in which the discharge originates, is hereby declared to be a public nuisance and subject to abatement . . . (as provided by the law)."

### Aid to Be Given States

Portions of the law promulgate intent to assist states and municipalities to control water pollution by providing for technical services and financial aid for formulation of stream pollution programs. A major portion is devoted to activities of the Surgeon General and Federal Security Administrator in obtaining abatement of pollution considered a public nuisance under the law.

Section 2, (e)(2) reads, "Whenever the Surgeon General, on the basis of reports, surveys and studies finds that any pollution declared to be a public nuisance," (as defined by the law), "is occurring he shall give formal notification thereof to the person or persons discharging any matter causing or contributing to such pollution and shall advise the water pollution agency or interstate agency of the state or states where such discharge or discharges originate of such notification." It further reads that notification shall specify reasonable time and may recommend reasonable and equitable remedial measures to secure abatement.

### Court Action May Be Asked

It points out that failure to commence action within specified time shall be made known to persons concerned by the Surgeon General. He shall also notify the proper agency of state or states concerned and notification may be accompanied by a recommendation that the agency initiate suit to abate the pollution in a court of proper jurisdiction.

The Federal Security Administrator is authorized to call a public hearing if within a reasonable time after the second notification persons concerned fail to initiate action to abate the pollution or the state water pollution or interstate agency fails to start suit to secure abatement.

Hearing is held in or near one or more places where discharges originate and before a board of five or more persons appointed by the administrator. Mem-

bers may be officers or employees of the FSA or water pollution or interstate agency of the state or states where discharges originate. Exception is that at least one member shall be from water pollution or interstate agency of state or states concerned, at least one from Department of Commerce and not less than a majority be persons other than FSA officers or employees. On basis of evidence presented, the board makes recommendations to the administrator concerning measures, if any, which it finds to be reasonable and equitable to secure abatement of pollution in question.

### Suit May Be Started

If persons concerned do not comply with board's recommendations within reasonable time the administrator, with consent of water pollution agency or any state officer or agency authorized to give such consent, may request the Attorney General of the U. S. to bring suit on behalf of the U. S. to secure abatement of the pollution.

Before and after suit is commenced any person or persons alleged to be discharging matter contributing to pollution of which abatement is sought may with consent of water pollution agency or any state officer or agency authorized to give such consent be joined as a defendant and court has power to enforce judgment against such defendant. Where two or more persons in different judicial districts are originally joined as defendants suit may be started in judicial district in which any discharge caused by any defendant occurs.

The law explains that court shall receive in evidence a transcript of board proceedings, a copy of its recommendations and such other evidence as the court deems proper. Giving due consideration to practicability and physical and economic feasibility of securing abatement of any pollution proved, the court has jurisdiction to enter such judgment and orders enforcing such judgment as the public interest and the equities of the case may require.

## Organization and—

(Continued From Page 75)

and higher operating costs of the railway system. Tests to determine best coordinated plan for installation of cathodic protection for a bare high pressure pipe line are being made with a by-products pipe line company.

The Columbus Committee is also working out the problem of isolating the trolley coach negative feeder and the overall program is progressing satisfactorily. The power company providing power for the transportation system has planned a program to check the potentials on all underground feeders. Due to economics, as in Cleveland, the trolley coaches soon may be replaced with gasoline or Diesel-driven buses, so the committee, sensing its greater responsibilities, has changed its name and interests to include problems outside the Metropolitan Columbus area.

### Problems in Toledo

Actual installation of a high output rectifier for insurance protection of a pipe company's high pressure by-products pipe line without prior co-

ordinated testing is the principal problem in the Toledo Committee. That even secondary benefits can be derived from such an association is indicated by another case coming before the committee. A concerted track bonding program on the part of an electric freight line and by use of interconnected overhead neutral ties of the power company made possible reduction of excessive drainage current from telephone cables to a substation.

In view of the Cleveland, Toledo and Detroit Committees' rectifier interference problems, reference is made to a paper entitled "Stray Currents from Cathodic Protection Installations," by C. A. Erickson, in which the author indicates the feeling that such interference problems that arise can be coordinated satisfactorily only by the active cooperation of all interested parties involved through the mutual efforts of an organized committee.

What about the need for such committees in other locations? In a rural area, a pipe company had its coated pipe line protected by a 500 milliamperere rectifier unit. A consulting engineering company placed a rectifier on a bare pipe crossing this protected line and without the knowledge of the coated pipe line company placed a solid bond between the two structures which permitted one ampere to flow. In a suburban area an engineering company placed a 20-ampere ground bed within 15 feet of an underground cable dip in a new housing development. These two cases indicate inadequate preliminary engineering for the planned protective systems.

### Informality Is Asset

Probably the major advantage derived from an organized Committee of this kind lies in its conference or simulated council character with each member having the opportunity to speak freely and informally. Discussion induces an awareness of mutual problems and recognition of possible economic loss which may be incurred by the other fellow usually brings willingness to accept the cooperatively planned solution. Also, such coordination of problems should assist each company to obtain pertinent pre-engineering information for new construction work, to permit a reduction in corrosion losses and maintenance expenses and at the same time to provide better services for its customers.

Condensed from a paper titled "Coordination of Corrosion Problems Through Organized Committees," by R. M. Lawall, Electrical Protection Engineer, Long Lines Dept., Cleveland Division, American Telephone and Telegraph Co., presented at Symposium of Underground Structure Corrosion, Niagara Frontier Section, NACE, Buffalo, New York, October 27-28, 1954.

## Haines Heads ASHACE

John E. Haines, Commercial Controls Division of Minneapolis-Honeywell Regulator Corp., was elected president of the American Society of Heating and Air-Conditioning Engineers during its 61st Annual Meeting in Philadelphia, January 24-27.

The Eleventh Annual Conference and Exhibition of NACE will be held in Chicago in March, 1955.

## The Vertical

392 pages, 8 1/2 x 11 in., 3272 E. 8, Cal. Per.

This book is a study of vertical propeller pump problems and its presents resistant materials, mended pump liquids and gases. The book is each providing subjects of design resources, performance characteristics, mixed pump selection and corrosive conditions of vertical propeller pump formulas and data.

## Symposium

Technical 88 inches, 88 1954, American Materials, 1, 3. Per copy.

Contains paper presented during held by AS Methods of Analysis of Sessions of Meeting of A 15, 1954. Properties of hydrocarbons, industrial exhaust and odor control subjects in pipeline and provided.

## Oklahoma

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## BOOK REVIEWS

**The Vertical Pump.**  $7\frac{3}{4} \times 10\frac{3}{4}$  inches, 392 pages, cloth. 1954. Johnston Pump Co., 3272 E. Foothill Blvd., Pasadena 8, Cal. Per Copy \$10.

This book provides a comprehensive study of vertical turbine, mixed flow and propeller pumps replete with tables, diagrams and illustrations (both pictorial and drawn). On the subject of corrosion it presents information on corrosion-resistant materials for pumps, recommended pump materials for corrosive liquids and general rules to be followed. The book is divided into five sections, each providing excellent coverage on the subjects of development of ground water resources; construction, design and performance characteristics of vertical turbine, mixed flow and propeller pumps; pump selection for hot, volatile, viscous and corrosive fluids; practical applications of vertical turbine, mixed flow and propeller pumps and engineering formulas and data.

**Symposium On Odor.** ASTM Special Technical Publication No. 164. 6 x 9 inches, 88 pages, paper. November, 1954. American Society for Testing Materials, 1916 Race St., Philadelphia 3. Per copy, \$2.25.

Contains papers and discussions presented during the Symposium on Odor held by ASTM Committee D-22 on Methods of Atmospheric Sampling and Analysis at the Tenth and Fifteenth Sessions of the Fifty-seventh Annual Meeting of ASTM in Chicago on June 15, 1954. Proposal for some basic definitions of odor, catalytic method of measuring hydrocarbon concentrations in industrial exhaust fumes, odor pollution and odor control methods are some of the subjects included. A general discussion on use of odorants in natural gas pipeline and bottled gas systems is provided.

## Oklahoma U. Short—

(Continued From Page 75)

1:55-2:35 pm—Electrical Grounding in Cathodically Protected Systems by O. W. Everett, Oklahoma Natural Gas Co.

3:10-3:50 pm—Corrosion Problems in Parallel and Crossing Systems by C. L. Mercer, Southwestern Bell Telephone Co.

4-4:40 pm—Group discussion.  
7 pm—Entertainment, motion pictures.

**Wednesday, April 6**

8:30-9:15 am—Views of Management on Corrosion Control by Carl Cloud, Mid South Gas Co.

9:20-10 am—Selling Corrosion Control to Management by J. C. Spalding, Jr., Sun Oil Co.

10:20-11 am—Corrosion-Resistant Metals and Alloys for Chemical Process Equipment by Wayne Z. Friend, International Nickel Co.

11-11:50 am—Plastics, Tapes and Coatings or Plastics as Pipeline Coatings by R. B. Bender, Plastic Engineering and Sales Corp.

**Pipeline Section**

1-1:40 pm—Sacrificial Anodes by P. F. Gorge, Dow Chemical Co.

1:55-2:35 pm—Protecting Pipelines by Impressed Voltage by Scott P. Ewing, Carter Oil Co.

3:10-3:50 pm—External Coatings for

Pipeline by W. H. Stewart, Sun Pipe Line Co.

4-4:40 pm—Unwanted Currents on Pipelines by James R. Cowles, Corrosion Engineer.

**Plant and Yards Section**

1-1:40 pm—Prevention of Caustic Embrittlement in Boilers by James S. Conners, Phillips Petroleum Co.

1:55-2:50 pm—Corrosion Control in Steam and Condensate Systems by John J. Maguire, W. H. & L. D. Betz Co.

3:10-3:50 pm—Corrosion Problems in Recirculating Cooling Tower Water Systems by R. S. Wise, National Aluminate Corp.

4-4:40 pm—Cathodic Protection of Tanks, Heaters and Plant Yards.

6:30 pm—Banquet.

**Thursday, April 7**

8:30-9:15 am—Test Methods for Corrosion Mitigation by James R. Cowles.

9:20-10 am—Microbiological Corrosion of Iron and Steel by D. M. Updegraff, Magnolia Petroleum Co.

10:20-11 am—Corrosion Problems in the Handling and Use of Sulfuric and Hydrochloric Acids by Harold E. Crook, National Zinc Co.

11:10-11:50 am—Selection of the Proper Surface Coating for a Given Application, by John W. Nee.

**Coatings Section**

1-1:40 pm—Discussion by Walter B. Meyer, St. Louis Metallizing Co.

1:55-2:35 pm—Use of Glass Coatings in Combating Corrosion by F. W. Nelson, A. O. Smith Corp.

3:10-3:50 pm—Discussion.

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## TECHNICAL REPORTS

Remittances must accompany all orders for literature the aggregate cost of which is less than \$5. Orders of value greater than \$5 will be invoiced if requested. Send orders to National Association of Corrosion Engineers, 1061 M & M Bldg., Houston, Texas.

Add 65c per package to the prices given below for Book Post Registry to all addresses outside the United States, Canada and Mexico.

- TP-1 Report on Field Testing of 32 Alloys in the Flow Streams of Seven Condensate Wells (Pub. 50-3) NACE members, \$8; Non-members, \$10 per copy.
- T-1A Survey of Corrosion Control in California Pumping Wells. A Report of T-1A on Corrosion in Oil and Gas Well Equipment, Los Angeles Area. Pub. 54-7. Per copy, \$5.00.
- T-1G Sulfide Corrosion Cracking of Oil Production Equipment. A Report of Technical Unit Committee T-1G on Sulfide Stress Corrosion Cracking. Pub. 54-5. \$5.00 Per Copy.
- TP-2 First Interim Report on Galvanic Anode Tests. (Pub. 50-2) NACE members, \$3; Non-members, \$5 per copy.
- T-2C Some Observations of Cathodic Protection Potential Criteria in Localized Pitting. A Report of T-2C on Minimum Current Requirements for Cathodic Protection. Pub. 54-2. Per Copy \$5.00.
- TP-3 First Interim Report on Ground Anode Tests. (Pub. 50-1) NACE members, \$3; Non-members, \$5 per copy.
- T-4B-3 Tests and Surveys for Lead Sheathed Cables in the Utilities Industry. Second Interim Report of Technical Unit Committee T-4B on Corrosion of Cable Sheaths. Publication 54-6. Per Copy \$5.00.
- T-4B-4 Pipe-Type Cable Corrosion Protection Practices in the Utilities Industry. First Interim Report of Technical Unit Committee T-4B on Corrosion of Cable Sheaths. Publication 54-3. Per Copy \$5.00.
- TP-1D Sour Oil Well Corrosion. Corrosion August, 1952, issue. NACE members, \$5.00; Non-members \$1 per copy.
- TP-1G Field Experience With Cracking of High Strength Steel in Sour Gas and Oil Wells. (Included in Symposium on Sulfide Stress Corrosion. (Pub. 52-3) \$1 per copy, 5 or more copies to one address, \$5.00 per copy.
- TP-5A Materials of Construction for Handling Sulfuric Acid. Corrosion, August, 1951, issue. NACE members, \$5.00; Non-members, \$1 per copy.
- TP-5C Stress Corrosion Cracking in Alkaline Solutions. (Pub. 51-3) Per Copy, \$5.00.
- T-6A Application Techniques, Physical Characteristics and Corrosion Resistance of Polyvinyl Chlor-Acetates. A Report of Unit Committee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion. Publication 54-4. Per Copy, \$5.00.
- TP-6G First Interim Report on Recommended Practices for Surface Preparation of Steel. (Pub. 50-5) Per copy, \$5.00.
- TP-6G Second Interim Report on Surface Preparation of Steels for Organic and Other Coatings. (Pub. 53-1) Per copy, \$1; five or more copies to one address, per copy \$5.00.
- TP-12 Report on Electrical Grounding Practices. Per copy \$5.00.
- TP-19 Corrosive Effects of Deicing Salts—A Progress Report by Technical Practices Committee 19. Corrosion, January, 1954, issue. NACE members \$5.00; Non-members \$1 per copy.

## Inter Society Corrosion Committee CORROSION MEETINGS CALENDAR

- March 7-11—National Association of Corrosion Engineers. Eleventh Annual Conference and Exhibition. Palmer House, Chicago, Illinois.
- March 8-10—American Institute of Electrical Engineers. Farm Electrification Conference. Morrison Hotel, Chicago, Illinois. (Sponsored by the Farm Electrification Subcommittee, AIEE)
- March 14-16—Society of Automotive Engineers, Inc. Golden Anniversary Production Meeting and Forum. Netherland-Plaza Hotel, Cincinnati, Ohio.
- March 15-17—American Institute of Electrical Engineers. Electrical Utilization of Aluminum Conference. William Penn Hotel, Pittsburgh, Penna. (Sponsored by the Power Division, AIEE)
- March 20-23—American Institute of Chemical Engineers. Louisville, Kentucky.
- March 28-29—American Institute of Electrical Engineers. Materials Handling Conference. Hotel Cleveland, Cleveland, Ohio. (Sponsored by the Subcommittee on Material Handling, of the G.I.A. Committee, AIEE)
- March 28-April 1—American Society for Metals. Western Metal Congress and Exposition. Los Angeles, California.
- April-May—American Institute of Electrical Engineers. Annual Conferences (in process of organization).
- April 12—American Gas Association. Distribution, Motor Vehicles, and Corrosion Conference. Netherland-Plaza Hotel, Cincinnati, Ohio.
- April 13-15—American Institute of Electrical Engineers, Committee on Technical Operations. Southern District Meeting. St. Petersburg, Florida.

April 18-21—Society of Automotive Engineers, Inc. Golden Anniversary Aeronautic Meeting, Aeronautic Production Forum, and Aircraft Engineering Display. Hotel Statler and McAlpin Hotel, New York, N.Y.

May—American Petroleum Institute, Subcommittee on Corrosion, St. Louis, Missouri. (During the 20th Midyear Meeting of the Division of Refining)

May 1 (week; tentative)—American Institute of Electrical Engineers, Committee on Technical Operations. Middle Eastern District Meeting (#2). Columbus, Ohio.

May 1-4—American Institute of Chemical Engineers. Houston, Texas.

May 9-10—American Gas Association. Gas Supply, Transmission, and Storage Conference. William Penn Hotel, Pittsburgh, Penna.

May 10-11—American Institute of Electrical Engineers. Electric Heating Conference. LaSalle Hotel, Chicago, Illinois. (Sponsored by the Electric Heating Committee, AIEE)

May 18-20—American Institute of Electrical Engineers. Telemetering. Morrison Hotel, Chicago, Illinois. (Sponsored by AIEE, IRE, ISA, IAS)

May 23-25—American Gas Association. Chemical, Engineering and Manufactured Gas Production Conference. Hotel New Yorker, New York, N.Y.


May 30-June 1—Chemical Institute of Canada. 38th Annual Conference and Exhibition, Quebec City, Que.

June—American Society of Heating and Ventilating Engineers. Semi-annual Meeting. San Francisco, California.

June 12-15—American Society of Refrigerating Engineers. Annual Convention. Hotel Schroeder, Milwaukee, Wisconsin.


June 12-17—Society of Automotive Engineers, Inc. Golden Anniversary Summer Meeting. Chalfonte-Haddon Hall, Atlantic City, N. J. (Special emphasis on corrosion)

(Continued on Page 80)



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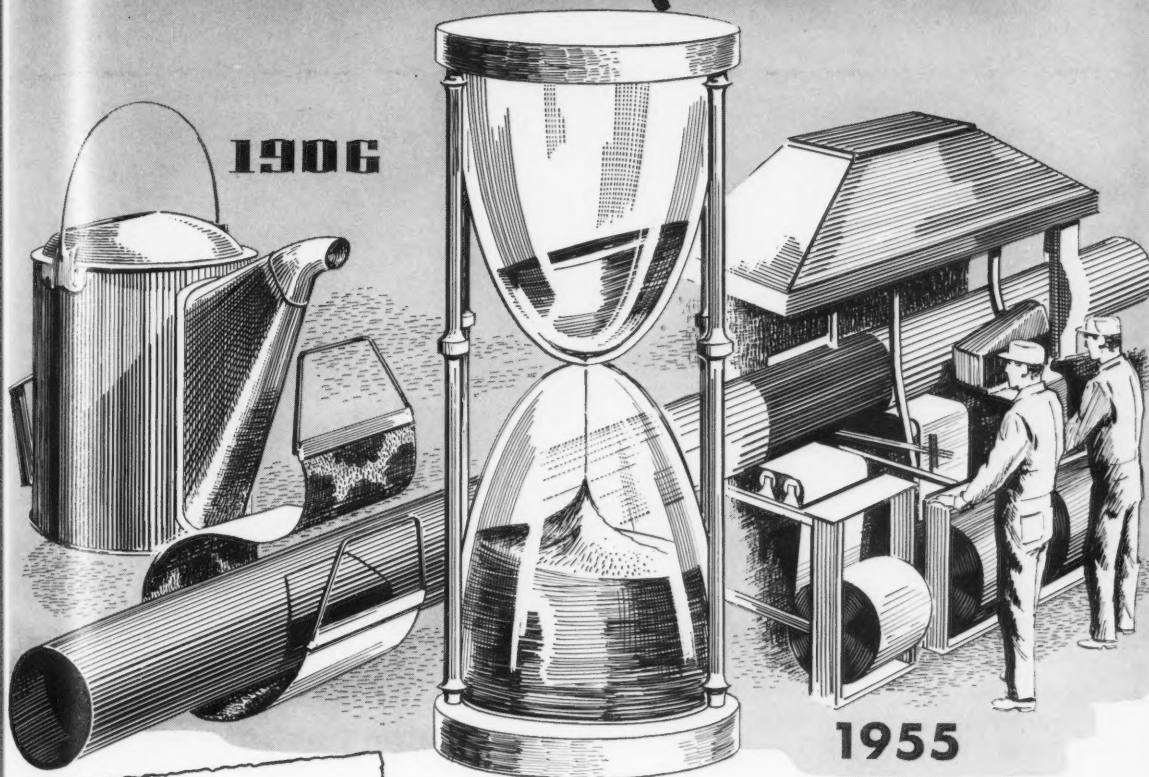
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## Corrosion Meetings—

(Continued From Page 78)

**June 13-15**—American Institute of Electrical Engineers, Magnetics. Pittsburgh, Penna. (Sponsored by the Subcommittee on Magnetics, of the Basic Sciences Committee)

**June 20-25**—American Electroplaters' Society. 42nd Annual AES Convention and 4th Industrial Finishing Exposition. Cleveland, Ohio.

**June 26-July 1**—American Society for Testing Materials. 1955 Annual Meeting. Chalfonte-Haddon Hall, Atlantic City, N. J.

**June 27-July 1**—American Institute of Electrical Engineers, Committee on

Technical Operations. 1955 Summer Meeting, General. New Ocean House, Swampscott, Massachusetts.

**July 18-22**—Gordon Research Conference, American Association for the Advancement of Science, Colby Junior College, New London, N. H.

**Aug. 15-17**—Society of Automotive Engineers, Inc. Golden Anniversary West Coast Meeting. Hotel Multnomah, Portland, Oregon.

**Sept. 12-15**—Society of Automotive Engineers, Inc. Golden Anniversary Tractor Meeting and Production Forum. Hotel Schroeder, Milwaukee, Wisconsin.

**Sept. 25-28**—American Institute of Chemical Engineers. Lake Placid, N. Y.

**Oct. 3-7**—American Institute of Electrical Engineers, Committee on Technical Operations. 1955 Fall Meeting, General. Morrison Hotel, Chicago, Illinois.

**Oct. 9-13**—Electrochemical Society, Inc. Fall Meeting. Pittsburgh, Penna.

**Oct. 11-15**—Society of Automotive Engineers, Inc. Golden Anniversary Aeronautic Meeting, Aircraft Production Forum, and Aircraft Engineering Display. Hotel Statler, Los Angeles, California.

**Oct. 17-21**—American Society for Metals. National Metal Congress and Exposition. Philadelphia, Penna.

**Oct. 31-Nov. 2**—Society of Automotive Engineers, Inc. Golden Anniversary Transportation Meeting. The Chase, St. Louis, Missouri.

**Nov. 2-4**—Society of Automotive Engineers, Inc. Golden Anniversary Diesel Engine Meeting. The Chase, St. Louis, Missouri.

**Nov. 9-10**—Society of Automotive Engineers, Inc. Golden Anniversary Fuels and Lubricants Meeting. The Bellevue-Stratford Hotel, Philadelphia, Penna.

**Nov. 27-30**—American Institute of Chemical Engineers. Detroit, Michigan.

**Nov. 27-30**—American Society of Refrigerating Engineers. Annual Convention. Hotel Statler, New York, N. Y. 1956

**Jan.**—American Society of Heating and Ventilating Engineers. Annual Meeting. Cincinnati, Ohio.

**Jan. 30-Feb. 3**—American Institute of Electrical Engineers, Committee on Technical Operations. 1956 Winter Meeting, General. Hotel Statler, New York, N. Y.

**Feb. 26-29**—American Institute of Chemical Engineers. Los Angeles, California.

**Feb. 27-March 2**—American Society for Testing Materials. 1956 Committee Week. Statler Hotel, Buffalo, N. Y.

**May**—American Institute of Chemical Engineers. Queen of Bermuda.

**May 2-4**—American Institute of Electrical Engineers, Committee on Technical Operations. North Eastern District Meeting. Rochester, N. Y.

**May 7-10**—American Gas Association. Distribution, Motor Vehicles, and Corrosion Conference. Congress Hotel, Chicago, Illinois.

**May 10-11**—American Gas Association. Gas Supply, Transmission, and Storage Conference. Conrad Hilton Hotel, Chicago, Illinois.

**May 21-23**—American Gas Association. Chemical, Engineering, and Manufactured Gas Production Conference. Hotel New Yorker, New York, N. Y.

**June**—American Society of Heating and Ventilating Engineers. Semi-annual Meeting. Washington, D. C.

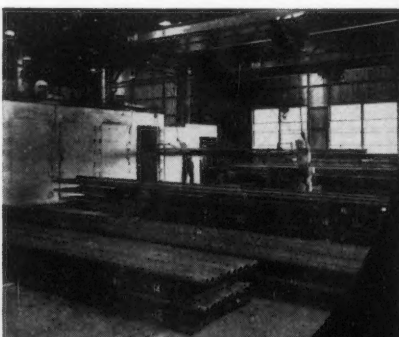
**June 17-22**—American Society for Testing Materials. 1956 Annual Meeting. Chalfonte-Haddon Hall Hotel, Atlantic City, N. J.

## Research makes TUBE-KOTE plastic linings BEST

Tube-Kote pioneered the use of plastic linings for pipe and other tubular oil field equipment. Since 1939 they have maintained a research laboratory devoted solely to developing, testing, and perfecting plastic formulas that would really combat corrosion, prevent paraffin deposition.

Tube-Kote is the world's largest company putting all its efforts in the one purpose of developing and manufacturing plastics for use in the oil field. It is a proved fact that Tube-Kote plastic linings—made best by research—and Tube-Kote's unique method of application of plastic to steel CANNOT BE DUPLICATED.

One end of the huge battery of bake ovens where Tube-Kote plastic linings are bonded to the metal. Electronic control keeps temperature within 1%.



Factory trained, field service engineers are available for consultation in all principal oil areas. Write today for free literature.



**TUBE-KOTE, INC.**

P. O. Box 20037

Houston 25, Texas

(Continued on Page 82)



**THIS  
WATERTIGHT  
SEAL  
MEANS LONGER  
LIFE TO  
PIPELINES!**



**Polyvinyl Chloride Tapes**

***Here are features old-style  
tapes can't match***

- Exceptional physical and dielectric strength.
- High resistance to shock, impact, acids, alkalis, and soil stress.
- Unequalled bond to metal pipe surfaces.
- Positive seal at helix of spiral.
- Extra thickness for extra protection.
- Low initial cost, lower final cost.

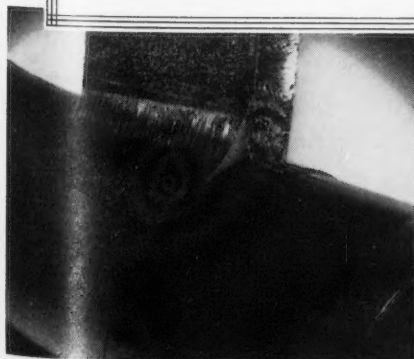
Due to their exceptional strength, new Plicoflex Polyvinyl Chloride Tapes can be wrapped tighter, expelling air and moisture and filling in imperfections in pipe surfaces to effect an unexcelled bond.

The photo above shows Plicoflex No. 330 tape being stripped from pipe. Note that the adhesive will not disbond from either the pipe surface or tape. No air bubbles or moisture droplets here! Pipe surface is effectively sealed against soil or atmosphere.

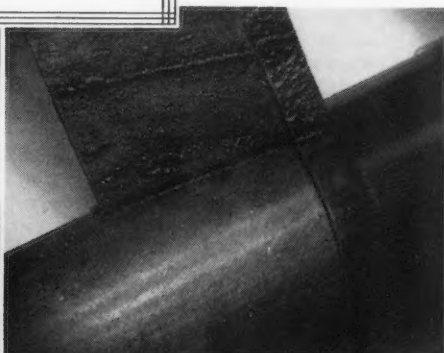
Illustrated below is Plicoflex No. 340, a laminated pvc-and-rubber tape which provides the added protection of a thick, continuous sheath of rubber firmly fused to the pipe surface.

Plicoflex Tapes are available in black, white, and 6 colors, providing a virtually maintenance-free color-coding system for above-ground installations.

Superior Plicoflex Adhesives of asphalt, coal tar or Neoprene base materials are available to suit your particular requirements.



*Plicoflex No. 340, applied with adhesive primer, demonstrates its superior bonding and sealing qualities.*



*Plicoflex No. 340, applied bare, still demonstrates its superior bonding and sealing qualities.*

***For more detailed information on the Plicoflex System, mail the coupon today.***

**PLICOFLEX, INC.**  
1566 E. Slauson Ave.  
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*More info on PLICOFLEX, please.*

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ADDRESS \_\_\_\_\_

CITY \_\_\_\_\_

STATE \_\_\_\_\_



## Corrosion Meetings—

(Continued From Page 80)

**June 25-29**—American Institute of Electrical Engineers, Committee on Technical Operations. 1956 Summer and Pacific General Meeting. San Francisco, California.

**Sept. 9-12**—American Institute of Chemical Engineers. Pittsburgh, Penna.

**Sept. 16-22**—American Society for Testing Materials. 1956 Pacific Coast Meeting. Statler Hotel, Los Angeles, California.

**Oct. 1-5**—American Institute of Electrical Engineers, Committee on Technical Operations. 1956 Fall General Meeting. Morrison Hotel, Chicago, Illinois.

**Oct. 28-Nov. 1**—Electrochemical Society, Inc. Fall Meeting. Cleveland, Ohio.

**Dec. 9-12**—American Institute of Chemical Engineers. Boston, Massachusetts.

1957

**Jan.**—American Society of Heating and Ventilating Engineers. Annual Meeting. Chicago, Illinois.

**Jan. 21-25**—American Institute of Electrical Engineers, Committee on Technical Operations. 1957 Winter Meeting. Hotel Statler, New York, N. Y.

**Feb. 4-8**—American Society for Testing Materials. 1957 Committee Week. Benjamin Franklin Hotel, Philadelphia, Penna.

**Spring** (tentative)—American Institute of Electrical Engineers, Committee on Technical Operations. Northeastern District Meeting. Pittsfield, Massachusetts.

**June 23-28**—American Society for Testing Materials. 1957 Annual Meeting. Chalfonte-Haddon Hall Hotel, Atlantic City, N. J.

**June 24-28** (tentative)—American Institute of Electrical Engineers, Committee on Technical Operations. 1957 Summer Meeting. General. Montreal, Quebec

**Oct. 6-10**—Electrochemical Society, Inc. Fall Meeting. Buffalo, N. Y.

**Jan. 27-31**—American Institute of Electrical Engineers, Committee on Technical Operations. 1958 Winter Meeting. General. New York, N. Y.

## Tracy Will Be Chairman Of Editorial Committee

Arthur W. Tracy, American Brass Co., Waterbury, Conn. for many years a member of the NACE Editorial Review Sub-Committee, has accepted the chairmanship of the committee effective with the 11th Annual Conference to be held at Chicago in March. Mr. Tracy, a member of NACE since 1945, is occupied with research and acts as a consultant on copper and copper alloys. He has more than 30 years' experience in corrosion work.

The committee over which he becomes chairman handles the material appearing in the Technical Section of Corrosion except Technical Committee Reports.



TRACY



Do you like it, dear? The beauty operator promised me THESE curls wouldn't pull out!

We don't recommend it as a hair style, but there is some merit to the lady's statement. That's why Standard Magnesium's VIBRA-PAK Anodes have a patented, *spiral* core. A core that just *won't* pull out.

There's just *one* of the many reasons for specifying VIBRA-PAK Anodes on your next corrosion job. There's also the fact that the magnesium used in each VIBRA-PAK Anode is *spectrographically analyzed*, to assure you of greater purity, more current per pound. And, of course, there's the time-saving factor which gives VIBRA-PAK its name; each anode comes to you pre-packaged in backfill; compacted and centered, ready to drop in the hole.

For longer life . . . more current . . . easier installation, specify VIBRA-PAK Magnesium Anodes on YOUR next job.



**Standard Magnesium Corporation**  
TULSA, OKLAHOMA

Pioneers of: SPECTROGRAPHICALLY ANALYZED ANODES AND CYLINDRICAL ANODES

## COKE BREEZE

### Backfill for Galvanic Anodes

Ideally suited for use with galvanic anodes. Has a high carbon content and comes in 1/8-inch by O size. In bulk or sacks.

GRAPHITE ANODES  
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ELECTROLYSIS SWITCHES

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## WmSON STYLE 4 THINSULATOR

The "THIN" insulator for pipe in casing

Clearance insures free movement into casing  
THINSULATOR band, flexible steel lined with synthetic rubber.  
Band clamped with steel stud bolts.

steel runners  
pipe line  
casing

SIZES  
6 x 10  
to  
36 x 40

THINSULATORS EQUALLY SPACED THRU CASING

A SNAP TO INSTALL  
just snap on pipe  
tighten studs . . .

## WmSON CENTERING CRADLE

short massive INSULATOR centers pipe at casing end permitting easy installation of "Z" BUSHING



- carries weight of backfill dirt and insulates pipe from casing
- EASY TO INSTALL: Simply lift pipe and slip into place

SIZES: any combination of pipe and casing sizes.

PIPE LINE

CASING

PIPE LINE

*Here's why...*  
Pipe line construction specs. include  
WmSON BUSHINGS, INSULATORS & CRADLES  
for cased crossings . . .

## WmSON "Z" BUSHING

OVERSIZED RING  
SLIDES EASILY OVER  
CASING END

THREADED TERMINALS  
IN CABLE UNION  
PLASTIC-COVERED  
AIRCRAFT CABLE

CUT-A-WAY  
VIEW SHOWING  
TOUGH, THICK  
SYNTHETIC RUBBER

**NO SHIELD REQUIRED**  
to protect tough sleeve  
from rocky backfill

SIZES:  
FOR PIPE 6" AND UP  
IN CASING 4" OR 6"  
LARGER

They are "ENGINEERED" for  
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# NEW PRODUCTS — Materials — Service — Literature

**A 21-page brochure** describing six Technical Measurement Corporation instruments including specifications and prices and full details of accessory equipment for use in radioisotope laboratories is available from Professional Instrument Corp., 177 Park St., New Haven, Conn.

**Ductile Irons** having fluidity, castability, ready machinability and low melting point of cast iron and strength, toughness, wear resistance and substantial ductility of steel are described in a 30-page booklet available from The International Nickel Co., Inc., 67 Wall St., New York 5. Booklet includes tables, graphs and photographic illustrations of properties of ductile iron.

**Development** of a hardware finish on die cast aluminum parts will allow designers to make use of aluminum die castings where a chrome-plated part is required according to Aluminum Company of America, 1501 Alcoa Bldg., Pittsburgh 19, developers of the finish. The improved as-cast finish makes plated aluminum die castings completely satisfactory from standpoint of service, weathering and corrosion the company says.

**Sili-Kool**, a heat-and-weather-resistant paint formulated of silicone and atomized silver aluminum is said to protect for more than a year such equipment as hot stacks, blistering boilers, steam pipe exhausts and manifolds and mufflers. C. H. Dragert Co., P. O. Box 5092, Dallas,

manufacturers of the paint claim it is pre-tested and money-back guaranteed to resist up to 1600 F while repelling rust and corrosion under severest weather conditions.

**A Six-Page Folder** describing need for intelligent control and testing to assure success of a water conditioning program is available from Hall Laboratories, Inc., Hagan Bldg., 323 Fourth Ave., Pittsburgh 30.

**Tuff-Tite**, a multi-purpose fastener with one-piece metal head and pre-assembled neoprene washer is described in a three-page Brochure TL 97 available from Townsend Co., New Brighton, Pa.

**Haveg 6310 Cement**, a carbon filled furan resin composition is described in a five-page Technical Bulletin No. 5 issued by Haveg Corp., a subsidiary of Continental-Diamond Fibre Co., Newark, Delaware. Bulletin includes guide to use of cement with findings and ratings based on company's research and experience.

**Nooter Corp.**, 1405 S. Second St., St. Louis 4, has published a 50-page booklet entitled "Custom-Fabricating Tanks and Pressure Vessels" which describes and illustrates various activities within the company's plant.

**Two Aluminum** scaffold-like truss units as working platforms in erection of steel trusses on portion of superstructure on the Richmond-San Rafael bridge being

constructed over the north arm of San Francisco Bay is expected to provide savings of several million dollars in labor and material costs according to report by Aluminum Company of America, 1501 Alcoa Bldg., Pittsburgh 19. They will be used 27 times for erection of approximately 15,000 tons of permanent steel trusses and are hoisted in place between two steel towers rising up to 170 ft. above water.

**A Corrosion-Resistant** cold drawn wrought iron tubing produced by A. M. Byers Co., is said to have high resistance to corrosion and fatigue failure. Manufacturer claims specific services in which tubing helps reduce frequency of repair or replacement include ammonia condensers, heat exchangers, pre-heaters, gas cooling apparatus, gasoline condensers, evaporators, vaporizers producing butane and propane gas and cooling pipe and steam condensers. Tubing is comprised of high purity iron and iron silicate in physical rather than chemical association the company says. Physical properties conform to those listed for welded wrought iron in ASTM-Specification A-72.

**A Chart Listing** new Kaiser aluminum products is available from Kaiser distributors or by writing Industrial Service Division 10, Kaiser Aluminum and Chemical Sales, Inc., 1924 Broadway, Oakland 12, Cal. Chart includes avail-

(Continued From Page 85)

## Corrosion engineers specify low-cost easy to fabricate BART Lectro-Clad steel pipe and sheet

In every industry faced with corrosion and contamination problems, Bart LECTRO-CLAD steel pipe, plate, sheet and fittings offer an economical, yet highly satisfactory and long-lasting solution. The ductile, adherent and pore-free electroplated nickel surface will withstand any fabricating process that the low carbon steel itself will withstand.

For low cost protection in all types of equipment for chemical, petroleum, pulp and paper and other process industries, specify Bart LECTRO-CLAD products.

Complete information and technical data on all sizes of steel pipe, sheet and fittings, LECTRO-CLAD with up to .015" of pure nickel, available on request.

Sheet of LECTRO-CLAD sheet steel being rolled, to fabricate industrial process equipment. The material can be welded, flame cut, and will withstand high temperatures without separating.



Photo: FARRAR and TRETTI



### BART MANUFACTURING CORPORATION

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## NEW PRODUCTS

(Continued From Page 84)

abilities for Kaiser Aluminum's standard truck body and truck trailer components and extruded floor sections, and a conversion table from old to new alloy designations. Chart is designed for use as wall chart, insertion in binder or for filing in standard size desk drawers or permanent filing cabinets.

**Porcenell**, a silicate coating produced by Vitreco, Inc., a corporation owned by Poor & Co., Chicago and Youngstown Sheet & Tubing Co., Youngstown, Ohio, is said to have abrasion resistance, scratch hardness, dielectric qualities and ease of application that make it a versatile coating. Manufacturer claims Porcenell is not subject to corrosion or organic change and is unaffected by heat up to its curing temperature, at least 900 F. Exclusive sales rights for Porcenell are held by Allied Porcenell, Inc., Phoenix, Arizona with national sales offices at 851 S. Market St., Waukegan, Illinois.

**Carpenter Steel Co.**, Reading, Pa., manufacturers No. 7-Mo (Type 329) stainless steel which it says offers excellent resistance to corrosive attack of certain nitric-hydrofluoric acid solutions. Recent test results indicate that this ability would make the alloy useful for equipment where such corrosive liquids are handled in pickling or similar operations, the company reports.

A fiberglass Reinforced epoxy construction material called Haveg 9710 is said to provide best combination of physical, thermal and chemical resistant properties along with characteristics which lend themselves to practical fabrication techniques. Haveg Corp., subsidiary of Continental-Diamond Fibre Co., Newark, Del., producers of the material have published a four-page Technical Bulletin No. 6 which describes Haveg 9710.

An Alloy Steel known as Wearpac is said to have unusually high resistance to impact and abrasion. American Steel Foundries, East Chicago, Ind., manufacturers of the metal, claim it is machinable, magnetic and that differential hardness of castings is obtainable when need exists for soft center section. Wearpac can be welded by conventional arc-welding methods with hardness affected only in immediate area of weld and no difficulties have been encountered in casting and material, the company says.

**Stainless Steel** has been selected as exterior sheathing for the Socony-Vacuum building now under construction at 150 E. 42nd St., New York. Galbreath Corp., owners of the 42-story office building claim influences leading to selection of stainless steel were durability and lasting beauty, weather, corrosion and fire resistance and economy of maintenance.

**Valves and Fittings** made from polyvinyl chloride called Luncor are described in a four-page circular available from the Lunkenheimer Co., Box 360, Cincinnati 14, Ohio.

A Portable, hand-operated heat tool said to burn clean, low-cost propane with a heat range of 4000 to 117,000 BTU per

(Continued on Page 86)

## The New Acidizing Inhibitor

Trade Mark

# RODINE

Reg. U.S. Pat. Off.

## No. 203

## Provides Positive Protection for

Well Tubing - Acid Storage Equipment at high as well as low temperatures. Designed specifically for acidizing.

An organic inhibitor, "RODINE" No. 203 does not contain sulphur or arsenic; ingredients known to stimulate embrittlement.

- Not destroyed by H<sub>2</sub>S.
- Does not cause localized pitting.
- Readily soluble in water or acid.
- Needs no dispersing agent.

## ECONOMICAL

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## EASY TO USE

Further Details on Request

Pioneering Research and Development Since 1914

## AMERICAN CHEMICAL PAINT COMPANY



Detroit, Michigan

General Offices: Ambler, Penna.

Niles, California



Windsor, Ontario

## NEW PRODUCTS

(Continued on Page 85)

hour is produced by Fire Gun Sales Corp., 2500 W. 7th Ave., Denver. The instrument called The Fire Gun is suited for such uses as soldering, tinning, brazing, preheating, thawing, plasticizing and paint removal and operates at about one-tenth the cost of an acetylene torch with same amount of heat, the company says.

**Stainless, nickel and Monel clad steels** called Colclad are described in a 51-page booklet published by Colviller Ltd., 195 W. George St., Glasgow, Scotland, developers of the metals. Booklet includes tables on specification, thermal conductivity, hot forming, gas cutting and stress relieving of the materials as well as information on physical tests, temperature variations, welding (including selection of electrodes), pickling and cleaning and protection of clad surfaces.

**Basic Courses** in the techniques of using radioisotopes have been announced by the Oak Ridge Institute of Nuclear Studies, P. O. Box 117, Oak Ridge, Tennessee. Courses which are open to scientists in all fields and designed for individuals starting work with isotopes are scheduled for January 10-February 4, February 21-March 18, May 2-May 25 (special class for noncitizens), June 6-July 1, July 11-August 5 and August 15-September 9. Further information and application blanks may be obtained by writing Ralph T. Overman, chairman, Special Training Division of the institute.

**Aluminum Sheets** and extruded panels produced by Aluminum Company of America, 1501 Alcoa Bldg., Pittsburgh 19, are being used in installation of 2442 aluminum highway signs on the 241-mile-long Ohio Turnpike. Manufacturer claims resistance of aluminum to corrosion increases life of message film in that rust stains do not deface signs when they are damaged. An aluminum sign measuring 10 by 20 feet will withstand wind-loading in excess of 100 miles an hour, the company reports.

**Metal Protection** and paint bonding for aluminum-alodine, zinc-lithoform (galvanized iron-cadmium) and steel-granodine are described in a four-page pamphlet published by American Chemical Paint Co., Ambler, Pa.

**Silicone** products are described in the eight-page 1955 Guide published by Dow Corning Corp., Midland, Mich. Guide contains tables, graphs, photographs and comparable data on various silicone products and organic materials they displace.

**An Inconel** pusher tray with channel frame which allows it to expand and contract when heated without becoming deformed is produced by Wiretex Manufacturing Co., Inc., 40 Mason St., Bridgeport, Conn. Company claims tray is presently being used successfully by customers for carbo-nitriding of small metal parts in an Ipsen furnace at temperature of 1500 F.

**Aluminum Alloy** designed primarily for cathodic protection of steel ship hulls in sea water is manufactured by Aluminum Company of America. Anodes cut

from metal which is called Alcoa Anode Plate are said to relieve corrosive attack on the hull. Protection of heat exchangers, storage tanks, various types of condensers and small metal-hulled boats are other potential applications reported by the company.

**Rigid Steel** electrical conduit said to have long-time resistance to severe corrosive atmospheres is manufactured by National Electric Products Corp., Pittsburgh. Called Superduct, the galvanized pipe is coated with vinyl chloride copolymer, pigmented and plasticized enamel finish inside and out to provide conduit with protection against corrosive influences.

**Silicate Coating** material similar to porcelain enamel is said to fuse to metal at temperatures from 900 to 1200 F. Manufactured by Poor and Co., and Youngstown Sheet & Tube Co., coating is applied in form of paint-like liquid after which water is evaporated and object fired in a furnace.

**Rigid Polyvinyl chloride** pipe is manufactured by Easton Plastic Products Co., Inc., 900 Line St., Easton, Pa. Manufacturer claims product is held to closer tolerances in concentricity and wall thickness than is now common in the metal-pipe field.

**A Subminiature** snap-action switch designated ISEL is produced by Micro Switch of Freeport, Ill., a division of Minneapolis-Honeywell Regulator Co. Manufacturer claims unit is completely sealed and recommends it for mobile, marine and aircraft applications where small size, light-weight and environment-proof construction are required. Switch gives trouble-free operation in temperatures ranging from -65 to 180 F and preliminary laboratory tests indicate a minimum mechanical life expectancy of 300,000 operations, the company says.

**A heat-and-weather-resistant** paint formulated of silicone and aluminum is manufactured by C. H. Dragert Co., Dallas. One coat of the paint will thoroughly protect for more than a year the hottest stacks, blistering boilers, steam pipes, Diesel and gas engines, exhausts, manifolds and mufflers, irrespective of most punishing temperatures and exposure, the company says.

**A Photometer** said to be a complete self-contained instrument for measuring absolute turbidity, dissymmetry and depolarization of dilute solutions of high molecular weight compounds is produced by Phoenix Precision Instrument Co., 3803-05 N. Fifth St., Philadelphia. Called the Brice-Phoenix Universal 1000 Series Light Scattering Photometer, the instrument is described in a 20-page booklet published by the company.

**A Rubber Compound** formulated of Buna N Polymer for sealing such vacuum applications as electronic devices, lens coating machinery, evaporators, high vacuum distillation electron microscopes and special testing devices is manufactured by Minnesota Rubber and Gasket Co., 3630 Wooddale Ave., Minneapolis. Designated as 366YV, the product is said to have advantages of high resistance to out-gassing at high temperatures and long service life in permanent installations.

**A Mono Chlorotrifluoroethylene** resin called Polyfluoron manufactured by Acme Resin of Forest Park, Ill., is said to be a uniform non-extruded pellet that has complete absence of fines. Company claims it is faster flowing, easier processing and more uniform than presently available polymers. D & R Pilot Plants of Hazardville, Conn., handles sales and technical services for product in the East.

**Q.A.I.**, a rust and corrosion inhibitor for instrument disinfecting solutions is produced by R. M. Hollingshead Corp., Camden, N. J. Manufacturer claims inhibitor does not add to toxicity of manufactured compounds and will not limit their germicidal properties. Laboratory tests show steel surgical instruments immersed for over three years in disinfectant solution using Q.A.I. in quaternary ammonium compound in dilution with Hyamine 2389 have no corrosion effects evident, the company says.

**An Eight-Page** booklet providing discussions on applications, processes, methods of installation and maintenance of stainless steel valves and fittings in the pulp and paper industry has been published by Cooper Alloy Foundry Co., Hillside, N. J. Booklet, entitled "Stainless Steel Valves and Fittings in the Pulp and Paper Industry" also includes diagrammatic illustrations and tables on mechanical properties, physical properties and corrosion resistance of the valves and fittings. Copies are available from the company on request.

**Alloy Tube Division** of Carpenter Steel Co., Union, N. J., has issued a 28-page catalog containing corrosion resistance tables, charts, field reports from users, detailed test results and similar engineering information on stainless steel alloys. Booklet also describes characteristics and performance of several super corrosion-resistant steels.

**A Calendered Rigid Polyvinyl chloride** sheet said to be adapted to production of corrosion-resistant tanks, ducts and similar structures by welding is manufactured by Bakelite Co., a Division of Union Carbide and Carbon Co., 300 Madison Ave., New York 17. Manufacturer claims product has high impact, tensile, flexural and welding strengths combined with resistance to chemicals and moisture and high heat distortion point and that it is easily machined and fabricated by techniques such as developed by American Agile Corp., facilitating construction with sheets as large as 4½ by 10 ft. It is ideal for such structures as self-supporting electroplating tanks, ducts and exhaust hoods for corrosive fumes and laboratory ware such as beakers, bottles and funnels for handling, storing and transporting corrosive liquids and solids the company says. Also Bakelite has published a 16-page booklet titled "Bakelite C-8 Epoxy Resins and Hardners" which describes use of these resins for tools, dies, jigs, fixtures, adhesives, laminating, casting, potting, embedding and encapsulating. Data on storage life and handling of the compounds including working life, mixing, fillers and cleaning equipment are explained. Copies may be obtained from the company.

(Continued on Page 87)

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An Electric thermoplast being marketed by Industrial Plastics Co., 1000 Ave., Minneapolis, of rigid polyethylene for tubes and pipes, gun, the 100 volts with watt element

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## NEW PRODUCTS

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**An Electric Hot Gas Welding Gun** for thermoplastics weighing 14 ounces is being marketed by Seelye Craftmen Industrial Plastics Division, 984 Central Ave., Minneapolis. Greatly increased use of rigid polyvinyl chloride and polyethylene for corrosion resistant structures and piping have created need for gun, the company says. It operates on 100 volts with choice of 180, 240 and 320 watt elements.

**Neoprene W**, a one-component neoprene synthetic coating applied by brush or spray is manufactured by Carbolite Co., 331 Thornton Ave., St. Louis. Manufacturer claims no catalysts or accelerators are required and recommends product for maximum maintenance protection against most acid and alkali fumes and splash and high humidity.

**Copper** and copper-alloy specifications are included in a tabbed 24-page reference manual (Anaconda Publication B-34R) published by The American Brass Co., a subsidiary of Anaconda Copper Mining Co., Waterbury 20, Conn. Manual contains ASTM, ASME, AWS, SAE, AMS, Federal, Army, Navy and Joint Army-Navy specifications and is divided into two sections. First section provides list of company's most generally used alloys together with applicable specifications of the agencies. Second lists specifications in numerical order with brief description of material such as alloy, grade, type, temper and anneal. Copies are available from the company at no cost on request.

**A Thermosetting Plastic** base surfacing called Ceilcrete "B" is produced by the Ceilcrete Co., 4874 Ridge Rd., Cleveland. Manufacturer recommends it for low-cost protection of concrete from fluorides, hydrofluoric acid and hydrofluoric acid solutions. Material can be applied to floors, trenches, tank bases and other concrete structures and density and stonelike hardness make it ideal for wide variety of applications where resistance to abrasion impact and constant immersion in acid solutions are important the company says.

**Aluminum Casting Alloys Handbook** is title of two-color 60-page booklet published by Federated Metals Division of American Smelting and Refining Co., 120 Broadway, New York 5. Descriptive material on metallurgy and casting practices and consolidation for easy reference of important specifications pertaining to aluminum casting alloys are included. Heat treatment, corrosion and effect of alloying elements such as copper, magnesium, silicon, manganese, iron, zinc, nickel and titanium are discussed. Gas removal, moisture effects, shrinkage, cracks, dross, pouring temperature and test bars are covered. Melting, fluxing and related problems of die casting are also described. Copies are free from the division on request.

**The Duriron Co., Inc.**, Dayton, will operate Enzinger Union Corp., Angola, (Continued on Page 88)

## COMBAT CORROSION!

Specify

TAPECOAT®

*... the Original Coal  
Tar Coating in Tape  
Form for Pipe,  
Pipe Joints, Couplings  
and Tanks*

TAPECOAT is a coal tar coating with a tar-saturated close-woven fabric as a carrier for speed of application. The coal tar is self-bonding and requires no foreign adhesives.

Because coal tar is nature's own protection against corrosion, TAPECOAT resists moisture, acids, alkalis, soil stress, electrolysis, chemical fumes, fly ash, salt water, salt-laden air, barnacles, and other severe corrosive and abrasive conditions above and below ground.



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TAPECOAT has proved its dependability over the years in serving gas and oil companies, railroads, telephone companies, air lines, shipbuilders and operators, water and sewage works, chemical and industrial plants, engineers and contractors . . . providing continuing protection against corrosion.

Write for descriptive brochure and prices.

**The TAPECOAT Company**

Originators of Coal Tar Tape Protection

1521 Lyons Street, Evanston, Illinois



## NEW PRODUCTS

(Continued From Page 87)

New York, as Enzinger Division of the Duriron Co., which will continue to produce stainless steel filters, multi-tube heat exchangers and special equipment fabricated from stainless steel.

**The ABC's of Spray Equipment**, is title of 64-page booklet published by The DeVilbiss Co., 300 Phillips Ave., Toledo 1. Booklet provides information on basic items of spray painting equipment from operation to maintenance and lists remedies for troubles which may affect a good finish.

**A Closed-Cell** sponge rubber material called Arco-cel is produced by Automotive Rubber Co., 12550 Beech Rd., Detroit. It is composed of individually sealed cells containing inert nitrogen and is available in natural rubber or as synthetic material. Manufacturer claims it is moisture-proof, shock-absorbent and light in weight and is excellent insulating material. A four-page brochure describing Arco-cel is available from the company.

**Properties of 18 Grades** of aluminum bronzes are listed in Technical Data Bulletin 15.100 available from WW Alloys, Inc., Division of Fan Steel Metallurgical Corp., 11644 Cloverdale Ave., Detroit 4. Properties include chemical composition, tensile and yield strengths, elongation, reduction in area and hardness. Suggested applications also are listed.

**How to Use and Specify** rigid plastic pipe and fittings is subject of 12-page catalog published by Alpha Plastics, Inc., 14 Northfield Rd., West Orange, N. J. Featured is corrosion chart classifying more than 275 corrosives rated according to desirability for use with Alpha No. 101 and No. 103 piping. Cat-

alog is available to qualified industrial engineers upon letterhead request.

**Jet application** of chemical solvents under high-pressure is explained in a two-page bulletin available from Mr. D. E. Shank, Advertising Dept., Dowell Inc., P. O. Box 536, Tulsa 1.

**Chemical treatment** of industrial water systems is considered in a six-page folder titled "Feeding of Chemicals" available from Hall Laboratories, Inc., 323 Fourth Ave., Pittsburgh 22. Folder includes examples of tube failures, plugged feed lines and other troubles caused by ill-advised chemical feeding on part of inexperienced personnel.

**Plastic Tape** which will not support combustion is produced by Minnesota Mining and Manufacturing Co., Dept. P-1631, St. Paul. Manufacturer recommends tape for joining cold and warm air ducts and sealing joints in home and industrial heating and air conditioning installations. Advantages include conformability and resistance to humidity changes and moisture-vapor. Vinyl plastic film backing withstands acids, alkalis, salt solutions, water, alcohols and hydrocarbons such as gasoline and kerosene, the company says.

**Twentieth Session** of Norelco X-ray Diffraction School is scheduled at North American Philips Co., Inc., 750 S. Fulton Ave., Mt. Vernon, N. Y., April 4-8. Basic subjects to be covered during first four days include X-ray diffraction, diffractometry, spectrography, new high and low temperature camera techniques, electron microscopy and electron diffraction. Fifth day is to be devoted to actual application problems and discussion of methods currently in use by researchers and industrial plants. Registration for first four days is limited to 125 and for fifth day to 150. There is no fee.

**High Range Accelerometer** made entirely of titanium and constructed to withstand up to 30,000 "G" without dam-

age is manufactured by Gulton Mfg. Corp., Metuchen, N. J. Designated Glennite Model A 330, unit is produced specifically for research in drop testing and impacts of projectiles against solid objects with measurement accuracy of plus-or-minus 10 percent from 5 to 10,000 "G" the company says. Manufacturer also produces modified Glennite amplifier F-406 used for coupling high impedance voltage sources in vacuum tube voltmeters, oscilloscopes and galvanometers and Glennite F 408 decade amplifier for general laboratory use.

**Flashlights**—two heavy-duty industrial-type—are manufactured by National Carbon Co., a Division of Union Carbide and Carbon Co., 30 E. 42nd St., New York 17. First is Eveready heavy-duty flashlight which manufacturer says has self-lubricating, hand-replaceable insulated slide switch, special lens guard made of polyethylene and insulated ethyl cellulose case that will not shatter, crack or dent, is resistant to temperature extremes and withstands deterioration from water, oils, gasoline, alcohols and acids. Second is Eveready Safety Flashlight which manufacturer claims has same features as heavy-duty model plus extra lamp in bottom cap so designed that if lamp is broken filament is snuffed out before lighting inflammable or explosive mixtures of gas in surrounding atmosphere. It is approved by U. S. Bureau of Mines and listed by Underwriters' Laboratories, Inc., the company says.

**Hi-Pure Cast Zinc Anodes** give more durable hull corrosion protection. Federated Metals Division, American Smelting and Refining Co., 120 Broadway, New York 5, says. Cast-in galvanized steel straps on anode furnished with stud mounting-holes may be welded directly to hull or other surface or mounted on steel studs, the company says. Anode weighs 24 pounds.

**BJ Mechanical Seal** said to be designed and tested to handle requirements of refinery service including hot asphalt and hot oil pumping up to 800 F is produced by Mechanical Seal Section, Byron Jackson Co., P. O. Box 2017, Terminal Annex, Los Angeles 54. Manufacturer claims seal requires no cold oil injection or auxiliary pumping for coolant and is corrosion-resistant.

**Condenser Tube corrosion** is described in a 28-page booklet titled "Life Extension for Condenser Tubes" published by Revere Copper and Brass Inc., 230 Park Ave., New York 17. Revere also has published "Fundamental Characteristics of Revere Metals" a 53-page booklet on cold working and hardness, annealing or recrystallization, corrosion and specifications of Revere metals; "Revere Copper and Copper Alloys" a 47-page booklet giving information on copper and its alloys including bronzes, bronzes and nickel silver; "Better Products With Electric Welded Tubing" a 31-page booklet describing electric welded tubing as structural metal; "Revere Phosphor Bronze" an eight-page booklet on characteristics of Revere Bronze and a chart of chemical and physical properties and typical uses of Revere alloys including condensed list of Revere products.

**Two Corrosion courses** and one on Principles of Organic Protective Coatings have been scheduled during the 1955 (Continued on Page 90)

*Specify*



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Consult us on your painting problem.  
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IN CANADA: Standard Chemical Limited and its Commercial  
Chemicals Division

## NEW PRODUCTS

(Continued From Page 88)

Spring Semester at Case Institute of Technology, Cleveland.

**Solu Bridge Automatic Rinse Tank Controller**, said to greatly reduce water consumption with increased plating quality results is produced by Industrial Instruments, Inc., Cedar Grove, N. J. Manufacturer claims water savings can be effected by more than 50 percent and that unit operates by continuous measurements of degree of electrolytic conductivity of rinsing waters and establishes permanent control of amount of fresh water admitted into rinse systems.

**A Guide to the Selection and Application**

of Superior Tubing is title of eight-page Bulletin 40 published by Superior Tube Co., 1714 Germantown Pike, Norristown, Pa. Catalog groups 46 analyses of stainless steel, nickel and nickel alloys, carbon and carbon alloy steels, beryllium copper and titanium. Short summary of principal properties of each analysis and its normal production limits is given. Copies are available from the company.

**Unichrome 5300**, a sprayable plastisol, said to permit spray application of vinyl plastisol films at room temperature to cold vertical surfaces to produce single coat, seamless, dry films up to 20 mils thick without sagging is produced by United Chromium, Inc. 100 E. 42nd St., New York 17. Manufacturer recommends product as effective, economical lining and exterior coating for tanks,

ducts and other equipment subjected to acids, alkalis, salts, oxidizing agents, moisture and other corrosives encountered in plating, chemical pharmaceutical, metal working, food and beverage industries. Applicators selected on basis of experience in working with different types of protective coatings as well as knowledge of industries in which protection against corrosion is required are being trained to apply the coating.

## PERSONALS

**R. H. Lueck** has been elected vice president in charge of the Research and Technical Department, American Can Co.

**Neil F. Richey** has been appointed director of Nuclear Equipment and Construction, Knapp Mills, Inc., of New York.

**John A. Field** has been named vice president in charge of sales development and related activities for Carbide and Carbon Chemicals Co., a Division of Union Carbide and Carbon Corp., 30 E. 42nd St., New York City. **R. L. Bateman** has been appointed director of Product Development for the company.

**R. P. Mills** has been named division manager and **J. A. Lehmann** division engineer of Electro Rust-Proofing Corporation's division office at 3 Rhodes Center, N.W., Atlanta.

**Leroy W. Davis** has been appointed technical superintendent at the Erie, Pa., aluminum forging plant of Kaiser Aluminum and Chemical Corp.

**Duncan W. Fraser**, American Locomotive Co., died December 20 at the Harkness Pavilion, Columbia-Presbyterian Medical Center in Manhattan at the age of 79. He had retired earlier this year from the position of board chairman which he assumed in 1945. Prior to becoming board chairman Mr. Fraser served as president of Alcoa from 1940 to 1945 and as a director from 1925 to 1939. His total service with Alcoa was 56 years.

**E. A. Tice** is being transferred to the New England Technical Field Section, Hartford, Conn., of the Development and Research Division, The International Nickel Co., Inc., 67 Wall St., New York 5. He has been a member of the division's Corrosion Engineering Section for the past eight years. **Howard N. Farmer, Jr.**, has joined the division's West Coast Technical Field Section at Los Angeles.

**A. T. Larned** has been appointed consulting civil engineer, **C. C. Bonin** as chief civil engineer and **A. C. Clogher** as an associate consulting engineer for Ebasco Services Co., Inc.

Dow Chemical Co., Midland, Mich., has named **Hilary A. Humble** as product sales manager for primary magnesium ingot, magnesium alloy ingot, magnesium extrusion and rolling ingot, flux and magnesium anodes. He was for five years product sales manager for cathodic protection activities in the company's Magnesium Department.



Hugh A. Brady



Yale W. Titterton

## NEW CATHODIC PROTECTION SERVICE FIRM

Dow magnesium anodes plus expert engineering and installation services are now offered to industry by a new firm, Yale W. Titterton and Hugh A. Brady, in charge of service, emphasize the company's experienced personnel and competitive position in the cathodic protection field.

- Consultation by competent engineers who helped pioneer the use of cathodic protection.
- DOW MAGNESIUM ANODES in every special size and alloy to meet all requirements.
- Name-brand cathodic protection instruments, materials and supplies.
- Turn-key jobs. Trained personnel, nationally known materials, and power equipment for complete installation.
- Large warehouse stocks in Tulsa and St. Louis.
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Call or write for cost estimates or quotations.



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## News about COATINGS for METALS

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# Protective plastisols gain new versatility

### Ucilon Protective Coatings solve many problems

A variety of Ucilon\* Protective Coating Systems, using either air-drying or baking coatings are available to handle problems that cannot be solved with plastisols. Applied like ordinary paint, Ucilon Coating Systems resist the same corrosives as plastisols and even some that plastisols do not withstand. The line includes systems based on vinyl, phenolic, chlorinated rubber and other chemical resisting coatings. Detailed information is provided in Bulletin MC-8. Send for it — no obligation.

\*Trade Mark

### Four types of drum linings handle most needs

Protection against drum corrosion and contamination of product is being obtained by many major steel drum suppliers by four basic types of Unichrome Drum Linings.

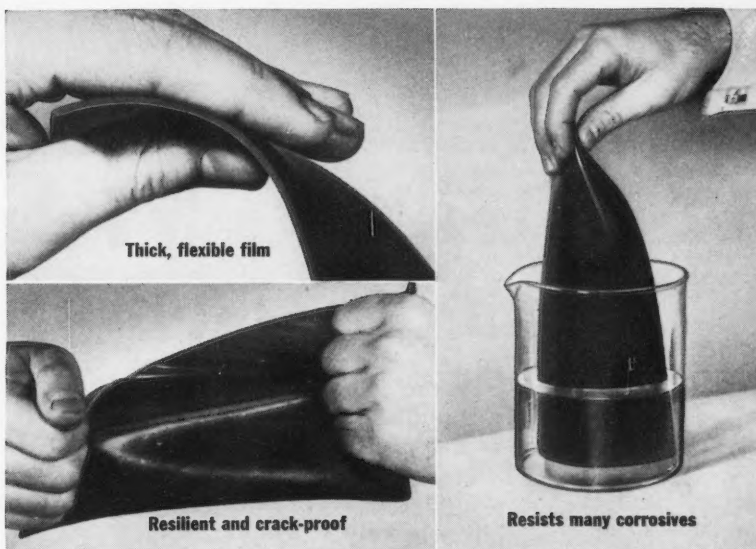
These include: (1) Phenolic base linings which are well suited for packaging solvents, oils, acid products and are used extensively in shipping detergents. (2) An epoxy resin base lining that not only gives essentially the same chemical resistance as the phenolics but also better flexibility and alkali resistance. (3) Vinyl base linings which are used effectively for packaging foods as well as caustics, latex, potable mineral oils and the like. (4) Plastisol drum linings which resist a wide range of products and are good for multiple trips.

Bulletin DL-2 gives you more details.

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*Advantages of Unichrome heavy-duty vinyl compounds now obtainable even with sprayed coatings*



Thick, flexible film

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Resists many corrosives

PLASTISOL compounds are liquids, which when heat cured, build up vinyl plastic finishes that look and feel like rubber, but there the resemblance ends. Plastisols offer truly remarkable chemical resistance, which is further fortified by the tough, substantial film thickness achieved in one coat.

#### SEAMLESS, THICK-FILM PROTECTION

Any metal surface that can be uniformly baked can now be strongly protected against severe and corrosive service conditions by Unichrome 4000 Series Plastisol Compounds—or the new Coating 5300. The first practical sprayable plastisol, Unichrome Coating 5300 fills the need for a plastisol suitable for application to products too large to be dip-coated.

A 20 mils thick, non-sagging coat can be applied even to cold vertical surfaces in just one application with

Coating 5300. That's 5 to 20 times thicker than ordinary coatings. Unichrome Series 4000 Plastisols, which are applied by almost any other conventional method, produce coatings up to  $\frac{3}{16}$ " thick. Plastisols can do jobs for which sheet materials have been used.

#### CHEMICAL RESISTANCE OF VINYL

Unichrome Plastisols offer seamless and pore-free protection against acids, alkalies, water, salt solutions and many other corrosive agents. They bake into an abrasion-resistant resilient coating that doesn't crack, chip or tear. With such protection, ordinary metals can often be used in place of costly alloys.

The chemical resistance, physical toughness, electrical insulating properties, and speed of curing of Unichrome Plastisols combine to offer engineers a new tool for protection and finishing. Send for Bulletin VP-1.



**PROOF!**

## It Costs Less to Apply Polyken Tape with the Motor-Driven Tapester

Note it takes only 5 men, including foreman, to apply Polyken Tape with the motor-driven Tapester. This means a major saving in labor and installation cost compared to many other types of coating. Polyken tape coatings control corrosion more efficiently and with less work.

### Engineering Service on Your Tape Job With No Obligation

Feel free to call us for complete information on the money-saving possibilities of applying Polyken tape to your pipe.

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**20,000 to  
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Polyethylene film, one of the most effective anti-corrosion barriers, is bonded to an extra-heavy adhesive mass, a good anti-corrosion barrier in itself. This double protection for pipes comes to you as a single wrap all ready to apply. There's no mixing, no heating. No liquids, solvents or thinners. Polyken Tape Coating goes on as a uniform coating.

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**CORROSION**

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# Corrosion Abstracts

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## 2. TESTING

### 2.4 Instrumentation

#### 2.4.3

Ultrasonic Testing of Mass Products in Water Immersion. (In English). G. KELLER. *Acta Tech. Acad. Sci. Hung.*, 7, No. 3-4, 359-387 (1953).

Testing equipment and methods permit reliable, swift detection and recording of discontinuities. Graphs, tables, diagrams, photographs, X-ray radiographs. 29 references.—MR. 7776

#### 2.4.3, 2.3.9

Some Industrial Applications of Microradiography. S. GOLDSPIEL AND F. BERNSTEIN. *Non-Destructive Testing*, 11, No. 5, 15-20; disc., 20 (1953).

In microradiography, which supplements photomicrography, a thin (~0.005-0.015 in.) slice of the material is radiographed with long-wave-length X-rays on a fine-grain film and the image is viewed by enlargement. Various applications are described, and particular reference is made to the preparation of non-ferrous specimens. Microradiography is recommended for investigating alloy systems. 22 references.—MA. 7727

#### 2.4.3, 2.3.9

New Methods Determine Grain Size Ultrasonically. N. GROSSMAN. *Iron Age*, 172, No. 27, 72-75 (1953) Dec. 31.

Description of grain size testing by standard Sperry ultrasonic reflectoscope. On alpha-brass rods the number of back reflections varied with grain size up to a wave-length/grain-size ratio of 30 to 1. Above this ratio a constant number of back reflections occurred.—BNF. 7720

#### 2.4.3, 2.3.9

Uses of Low-Voltage X-Ray Tubes with Thin Beryllium Windows in Non-Destructive Testing. T. H. ROGERS. *Non-Destructive Testing*, 11, No. 4, 34-38 (1953).

A description is given of a 50-kV. X-ray tube incorporating a beryllium window which, having a low X-ray absorption, allows the transmission of very long wave-length radiation. The relative total intensities of 50 kV. radiation transmitted by beryllium, Pyrex, and aluminum windows 1.0 mm. thick, are 100, 7.9 and 4.9 respectively. The many benefits accruing from use of beryllium windows and the merits of even thinner windows than those at present used, are discussed. Such tubes have been applied successfully to: (1) X-ray diffraction; (2) thickness gauging of sheet metal; (3) microradiography; (4) measurement of thickness of coatings, e.g. tin, zinc, and cadmium on steel, by the measurement of the intensity of the fluorescent radiation excited in the base metal; (5) examination of spot welds in thin light-alloy sheet; and (6) qualita-

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## CODE OF AGENCIES SUPPLYING CORROSION ABSTRACTS

Neither NACE nor the sources listed below furnish reprint copies.

ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Ontario.

AWWA—Journal, American Water Works Association, Amer. Water Works Assoc., 521 Fifth Ave., New York 17, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BTR—Battelle Technical Review, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.

CBEC—Centre Belge d'Etude de la Corrosion (CEBELCOR), 17 rue des Drapiers, Brussels, Belgium.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

EL—Electroplating. 83/85 Udney Park Road, Teddington, Middlesex, England.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.

IIM—Transactions, The Indian Institute of Metals, 23-B, Netaji Subhas Road, P. O. Box 737, Calcutta, India.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum. 26 Portland Place, London W#1, England.

JSPS—Japan Society for the Promotion of Science, Address: Mr. Hayata Shigeno, Secretary, Committee of Preventing Corrosion, c/o Government Chemical Industrial Research Institute, 1-Chrome Nakameguro, Meguro-ku, Tokyo, Japan.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

MI—Metallurgia Italiana, Associazione Italiana di Metallurgia. Via S. Paolo, 10, Milano, Italia.

MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

NSA—Nuclear Science Abstracts. United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.

PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.

SE—Stahl und Eisen, Verlag Stahlisen, M. B. H., Dusseldorf, August-Thyssen Str. 1. Postcheck Kohn 4110, (22a) Dusseldorf, Germany.

TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.

UOP—Universal Oil Products. 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.





## HOT DOPE

Straight from the Kettle  
on PIPE PROTECTION

By Boyd Mayes

Seems like the politicians in Washington are trying to outdo the TV spectaculars. So far I think Washington is ahead with its show that ended in early December. Now seems a couple of other big "productions" may get underway soon. Maybe the Dixon-Yates contract for TVA will be one. When you see through all the smoke, looks like it's a question of Public vs. Private Power. Considering everything—I'm pretty pleased with what this country has done under free and private enterprise, so I lean that way.

If it's a matter of size of the job to be done, look what the oil and gas industry has been able to do under a free economy. I'm sold on it. Although coating and wrapping pipe is only a small part of the oil and gas industry, it's mighty important—and we've been putting PERMANENCE in pipe for the industry for over a quarter of a century with the best in men, equipment and materials.

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tive chemical analysis of substances by measurement of their X-ray absorption, and by measurement of the fluorescent radiations they emit under X-ray excitation.—MA. 7791

### 2.4.3, 2.3.9

**Reduction of Exposure Time in Gamma Radiography.** J. J. HIRSCHFIELD AND D. T. O'CONNOR. *Non-Destructive Testing*, 11, No. 4, 28-33 (1953).

Following a review of the factors controlling image sharpness in  $\gamma$ -radiographs, it is concluded that exposures may be reduced by: 1. using source-film distances shorter than commonly employed; 2. using a high-density source of small geometric size; 3. using fast film between fluorescent (salt) intensifying screens, with lead filters; 4. increasing the development time; and 5. exposing (with salt screens) at low temperature. The effect of these factors and the limitations on their use are indicated with reference to their effects on unsharpness due to film and screen combination, geometric, and scatter factors. The results are illustrated by curves relating sensitivity and technique for various metals and radiographic techniques.—MA. 7709

### 2.4.3, 3.7.3

**Experiences with Ultrasonic Testing of Welds.** H. KRACHTER. *Stahl und Eisen*, 73, No. 5, 279-283 (1953).

Ultrasonic testing procedure. Application of angular probe heads; single vs. twin-transducer reflection methods. Detection of cracks, porosity, and nonmetallic inclusions in welds up to 35% deep; and correlation of results with radiography (X and gamma rays). Results obtained with twin-transducer method on welded steel specimens of various thicknesses and compositions. Evaluation of ultrasonic records by observing the shape of the defect echo and by determining the intensity ratio of defect echo to terminal echo. Advantages of ultrasonic testing over other test methods, for plate thicknesses of over 1/2 inch: Lower investment cost; lower operating cost; smaller space requirement, and lower labor cost. (Translation available: Henry Brucher, P. O. Box 157, Altadena, California.) 7773

### 2.4.3, 3.7.3

**Radiographic Examination of Welds. A Complete Assessment of Defects in Terms of Tensile and Fatigue Strength.** (In Italian). OSCAR MASI AND ANTONIO ERRA. *Metallurgia italiana*, 45, No. 8, 273-283 (1953) August.

Tables, diagrams, graphs, photographs. 7 references.—BTR. 7788

## 3. CHARACTERISTIC CORROSION PHENOMENA

### 3.2 Forms

#### 3.2.2, 6.2.5, 3.5.9

**Embrittlement of Austenitic Chrome-Nickel Steels on High Temperatures.** Pt. I. G. HOCH. *Arch. Eisenhüttenw.*, 23, No. 7-8, 257-263 (1953).

Comprehensive investigation of the various embrittlement phenomena of austenitic chromium-nickel steels in the temperature range of 570-1830°F. to obtain quantitative data on the types of embrittlement. Embrittlement at high temperatures as revealed by notched-bar impact tests and

bend tests. Data on composition, structure, and thermomagnetic behavior of 68 steels containing 0.02, 0.04, 0.10 and 0.35% carbon, 12-27% chromium, 8-20% nickel, and in part also niobium, titanium, and silicon—niobium. Particulars on thermomagnetic behavior of steels showing phase transformations or Curie point transformations, respectively, differing in magnitude. Impact values at room temperature after heating for 1000 hrs. at 570-1830°F. preceded by a water quench from 2010°F. (Translation available: Henry Brucher, P. O. Box 157, Altadena, California.) 7711

#### 3.2.2, 6.3.6

**Intercrystalline Brittleness (of Beta Brass).** A. R. BAILEY, S. MORRIS AND A. J. K. WIESIOLEK. *Metal Ind.*, 83, No. 25, 497-498 (1953).

In a comprehensive investigation into the intercrystalline failure of brass in various media, especially in sea-water, delayed intercrystalline failure in air was observed in sand-cast ternary  $\beta$ -brass, containing approximately 4% aluminum, under sustained tensile stress. This was also observed unexpectedly in a binary  $\beta$ -alloy. One possible explanation is the presence of impurities which by concentrating at the crystal boundaries, could produce intercrystalline weaknesses in the binary alloy and could accentuate that already present in the aluminum brasses, although all the alloys were made from high-purity constituents and no evidence by ordinary metallographic examination has yet been obtained of the presence of a second phase at the grain boundaries of any of the alloys. The presence of almost submicroscopic intercrystalline films of the brittle  $\gamma$ -phase was considered as a possible cause. 8 references.—MA. 7689

#### 3.2.2, 6.3.6

**Theoretical and Experimental Study of Some Phenomena of Dezincification in Brasses. Part I: Types of Corrosion in Brasses—Dezincification: Causes and Theories.** (In Italian). P. LOMBARDI. *Metallurgia italiana*, 45, No. 12, 449-456 (1953) December.

Investigation on the various types of corrosion encountered in copper zinc alloys, exact definition of the aspect of the dezincification corrosion, and description of the apparent course of the phenomenon: parts of the piece of brass result enriched with copper, as if, by particular phenomena, a preferential solution were to take place in the zinc.

Report of the conclusions of studies carried out by various researchers, through which are highlighted the defects of the different theories, reaching the most probable and the most confirmed, by which the phenomenon of the dezincification is not to be ascribed to the zinc, but to the action of the copper, which dissolving together with the zinc, may be redeposited in some parts according to general electrochemical laws. The phenomenon, as seen by the most recent theory, is described and commented in its phases and explained as an electrochemical phenomenon.—Mt. 7759

#### 3.2.3, 1.3

**The Sealing of Alloys.** (In German). O. KUBASCHOWSKI AND O. VON GOLDBECK. *Metallüberfläche*, A, 7, No. 8, A113-A118 (1953) August.

A survey of the literature (51 references). Homogeneous scales; cathodic oxidation due to molybdenum trioxide; the time-law of increase of thickness; hetero-

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geneous scales; formation of double oxides. Contents are mostly covered, in greater detail, in the book, "The Oxidation of Metals", by O. Kubaschewski and B. E. Hopkins. (See Card No. 6347, classified 3.2.3, 3.5.9, 1.6). 7764

### 3.2.3, 3.5.9

**Electron-Microscope Investigations on the Oxidation Process of Metals.** (In German). GERHARD PFEFFERKORN. *Naturwissenschaften*, 40, 551-552 (1953) November.

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elevated temperatures begins with the formation of thin oxide layers which grow thicker as the reaction continues. When examined under an electron microscope, the oxide films appear densely covered with fine needles, interspersed occasionally with thin leaflets. Fine needles begin to grow from the surface shortly after the first tarnish color appears. On continued oxidation, more fine needles form and, simultaneously, the older ones grow thicker and longer. The hot needles adhere to each other where they meet and oxide layers are deposited around the point of contact. Finally all the needles grow together at their bases, resulting in a compact oxide layer which continues to grow in thickness. The original needles formed at higher temperatures are less numerous but thicker than those formed at lower temperatures. Melting processes start far below the melting point of the oxide. Because the needles continue to grow at the top, metal ions or oxide molecules must be transported there from the interior or along the surface. The average thickness of the needles corresponds to the dimensions of the ideal crystal lattice occurring in all crystallization processes. The needle structure does, however, seem to acquire and incorporate certain defects during its growth. At these weak points the needles are easily broken by the electron stream.

These experiments also showed that some metal oxides, designated as 'pore-free', have a loose external layer in the form of a needle forest. This layer can participate significantly in the oxidation process because the increased surface area greatly facilitates the chemisorption of oxygen.—PDA. 7828

### 3.2.3, 6.3.6

**Electron-Diffraction Studies of Oxide Films Formed on Metals and Alloys. II. Selective Oxidation of (Copper) Alloys.** (In English). GORO HONJO. *J. Phys. Soc. Japan*, 8, No. 1, 113-118 (1953) Jan./Feb.; Cf. *ibid*, 4, 330 (1949).

The surface oxidation of copper alloys containing respectively 0.3% beryllium, 0.5% aluminum, 0.1% magnesium, 7% manganese, and 7% nickel, and of an iron alloy containing 13% aluminum, was studied by electron diffraction at 300°-900°C. and at air pressures ranging from 10<sup>-4</sup> to 760

mm.Hg. Selective oxidation of the base component of the alloys occurs generally, at sufficient reduced pressure and high temperatures, even in the case of those alloys which showed no such effect in Miyake's work done in the open air [*Sci. Papers, Inst. Phys. Chem. Research Tokyo*, Vol. 29, 167 (1936)]. In the case of iron-aluminum alloy, the surface of the alloy becomes covered with a film of  $\gamma\text{-Al}_2\text{O}_3$  which, provided that the subsequent oxidation is sufficiently drastic, is followed by the production of  $\text{Fe}_3\text{O}_4$  or  $\text{Fe}_2\text{O}_3$ , according to the pressure. Protection by the film of  $\text{Al}_2\text{O}_3$  against subsequent corrosion depends on the conditions of formation of the film. High secondary-electron emission from the copper-beryllium alloy is attributed to the orientation of the selective oxidation product,  $\text{BeO}$ , produced on the alloy. An unknown oxide of nickel of spinel-type structure, with lattice constant 8.23 Å, was produced on the Cu-Ni alloy.—MA. 7719

### 3.2.3, 6.3.13, 3.8.4

**High Pressure Oxidation of Metals. Technical Report No. 5. Tantalum in Oxygen.** ROBERT C. PETERSON, W. MARTIN FASSELL, JR., AND MILTON E. WADSWORTH. *Utah Univ. U. S. Atomic Energy Comm. Publ.*, (NP-4998), October 10, 1953, 31 pp.

The temperature and pressure dependence of the reaction of tantalum in oxygen were investigated from 500 to 1000°C. at pressures from 10 mm. Hg to 600 psi total oxygen pressure. Tantalum was found to oxidize linearly under the above conditions. Three distinct regions of temperature dependence were found with different energies of activation. From 500 to 600°C. the rate of oxidation of tantalum was found to be essentially independent of the oxygen pressure at the pressure investigated. From 600 to 800°C. the oxidation rate increases rapidly with an increase in pressure. The dependence of the oxidation rate on the bulk concentration may be expressed by  $V=k'\theta$  where  $k'$  is the specific rate constant and

$$\theta = \frac{k_1 k_{O_2}}{1 + k_1 k_{O_2}}$$

where  $k_1$  is the equilibrium constant for the adsorption of oxygen on tantalum.—NSA. 7805

### 3.2.3, 6.4.2, 5.4.2

**Structure of the Oxide Formed on the Surface of Aluminum.** (In Russian). M. S. BELETSKII. *Doklady Akad. Nauk S.S.S.R.*, 91, No. 1, 89-91 (1953) July 1; *Chem. Abstracts*, 48, No. 1, 14 (1954) Jan. 10.

The oxide layer on aluminum surfaces appears to consist of a nearly monatomic layer of oxygen held by relatively weak attraction existing between aluminum and oxygen atoms, in which 3p electrons of 2 atoms of aluminum are transferred to the 2p shell of adsorbed oxygen atoms after dissociation of the oxygen molecule. Thus there is formed a unimolecular film of two-dimensional  $\text{Al}_2\text{O}$  which does not give diffraction patterns by X-ray or electron-microscopic methods. If the oxidation occurs at elevated temperature, the two 3s electrons of aluminum also participate and form crystalline  $\text{Al}_2\text{O}_3$ ; such a situation occurs in oxidation of a spray of molten aluminum droplets which consist of  $\text{Al}_2\text{O}$  and  $\text{Al}_2\text{O}_3$  ( $\alpha$ -form) as shown by X-ray examination; heating in air to 1250°C. converts these particles completely to  $\text{Al}_2\text{O}_3$  ( $\alpha$ -form). Crystals of  $\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$  (boehmite) on heating 480°C. yield the  $\gamma$ -oxide

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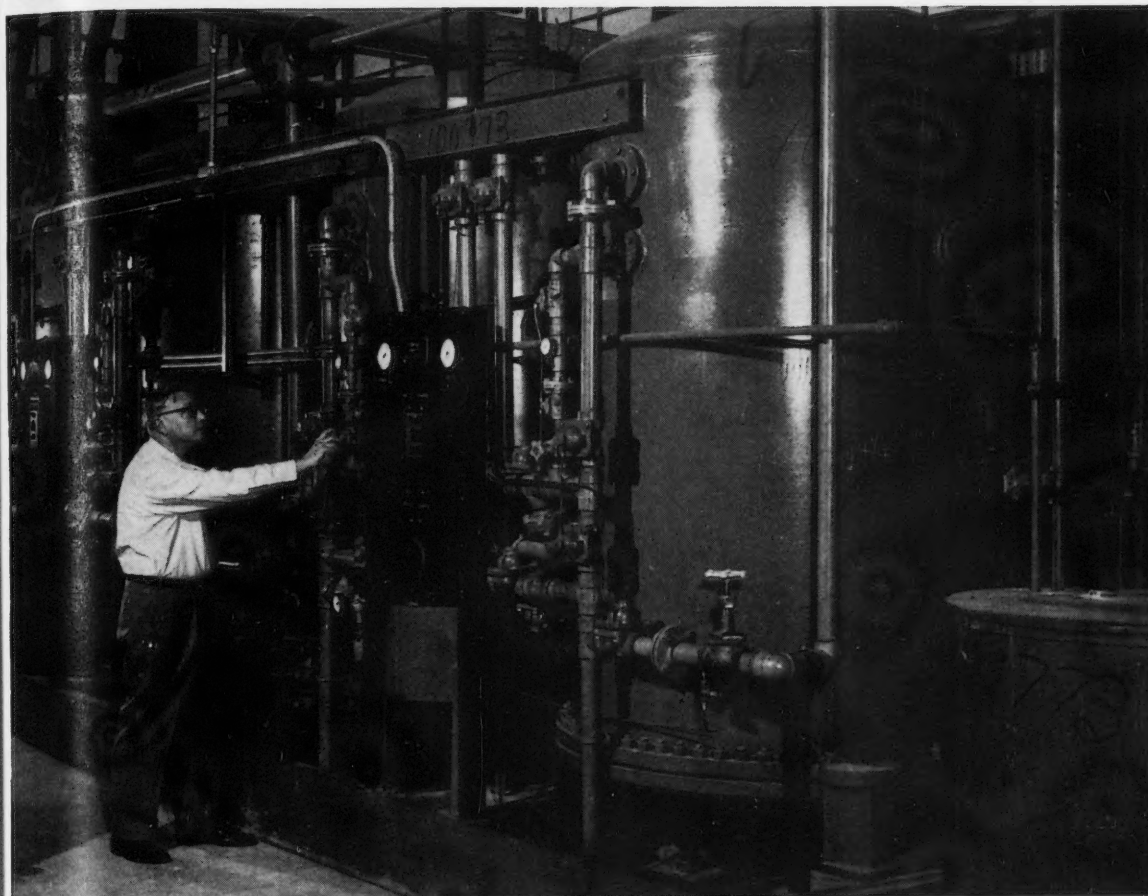
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with crystal particles of about 20Å. Absorption of  $H_2O$  vapor by this oxide (I) and by the so-called medicinal powder (II) (oxidation product of finely powdered aluminum under isothermal conditions at room temperature) was examined. II in taking up some 5%  $H_2O$  becomes rapidly saturated, whereas I prepared at 480°C. takes up 21%  $H_2O$  and I prepared at 500°C. takes up 18%  $H_2O$ . I prepared at 800°C. takes up but 10%  $H_2O$ . This can be explained by reduced amount of free surface in the specimens made at higher temperature. The low level of  $H_2O$  absorption by II is explained by the structure of the oxide layer on its surface. I immersed in  $H_2O$  undergoes no change, but I changes to boehmite and finally to bayerite by the reaction sequence such as;  $Al_2O_3 + 3H_2O \rightarrow 2Al(OH)_3 + 2H_2 \rightarrow Al_2O_3 \cdot 2H_2O$ ;  $Al_2O_3 + 2H_2 \rightarrow 2Al(OH)_3 + 2H_2O$ ;  $2Al(OH)_3 \rightarrow Al_2O_3 \cdot 2H_2O$ .—ALL. 7699

### 3.5 Physical and Mechanical Effects

#### 3.5.8

**The Behaviour of Metals Under Dynamic Loading.** D. S. CLARK. *Metal Progress*, 64, No. 5, 67-73 (1953) Nov.

Condensed version of the 1953 Campbell Memorial Lecture of the American Society of Metals. Discussion limited to the manner in which metals respond to stresses imposed in a short period. After a historical note, considers dynamic stress-strain relations, other tension-impact properties (including a table of static and dynamic tensile properties of steel, copper, aluminum, Duralumin and Dow J magnesium-alloy), delay of plastic strain, pre-yield micro

strain, mechanism of delay time (in which the mechanism of the yield point in low-carbon steel is discussed in terms of dislocations).—BNF. 7744

#### 3.5.8, 2.1.1

**Investigation of the Statistical Nature of the Fatigue of Metals.** G. E. DIETER AND R. F. MEHL. Nat'l. Advisory Comm. Aeronaut., Tech. Note 3019, Step., 1953, 25 pp.

Utilizing statistical methods, a study was made of the scatter found with 2S, 24S and 75S aluminum alloys, also with a steel having in one case a coarse pearlite structure and in the other a coarse spheroidised structure with the same tensile strength.—BNF. 7740

#### 3.5.8, 3.5.3

**How Metals Wear.** W. E. JOMINY. *S. A. E. Journal*, 61, No. 8, 23-25 (1953).

Wear can be produced by: a. cutting (similar to the action of a file on a soft metal), b. abrasion (action of dust embedded in a soft metal), c. welding due to pressure and heat generated by friction, d. corrosion, and e. fatigue. Non-metallic coatings help to prevent galling. Corrosion products often act as abrasives and accelerate wear. Chromium-plating improves the wear-resistance because of increase in hardness and corrosion-resistance.—MA. 7748

#### 3.5.8, 3.7.3

**Effect of Low-Temperature Stress-Relieving on Stress Corrosion Cracking.** C. R. MCKINSEY. Linde Air Prods. Co. Paper before AWS, 34th Nat. Fall Mtg., Cleveland, October 19-23, 1953. *Welding J.*, Res. Supplement, 33, No. 4, 161s-166s (1954) April.

Stress-corrosion cracking was produced

in some steels in the as-welded condition by exposure to certain nitrate solutions under proper conditions of temperature and time. Severity of stress-corrosion cracking increased as the carbon content decreased; both rimmed and killed steels were susceptible. Controlled low-temperature stress-relieving was effective in reducing the susceptibility of welded plates to stress-corrosion cracking. Steel plates investigated contained from 0.11-0.52 nickel. Tables, photomicrographs and 11 references.—INCO. 7845

### 3.6 Electrochemical Effects

#### 3.6.8

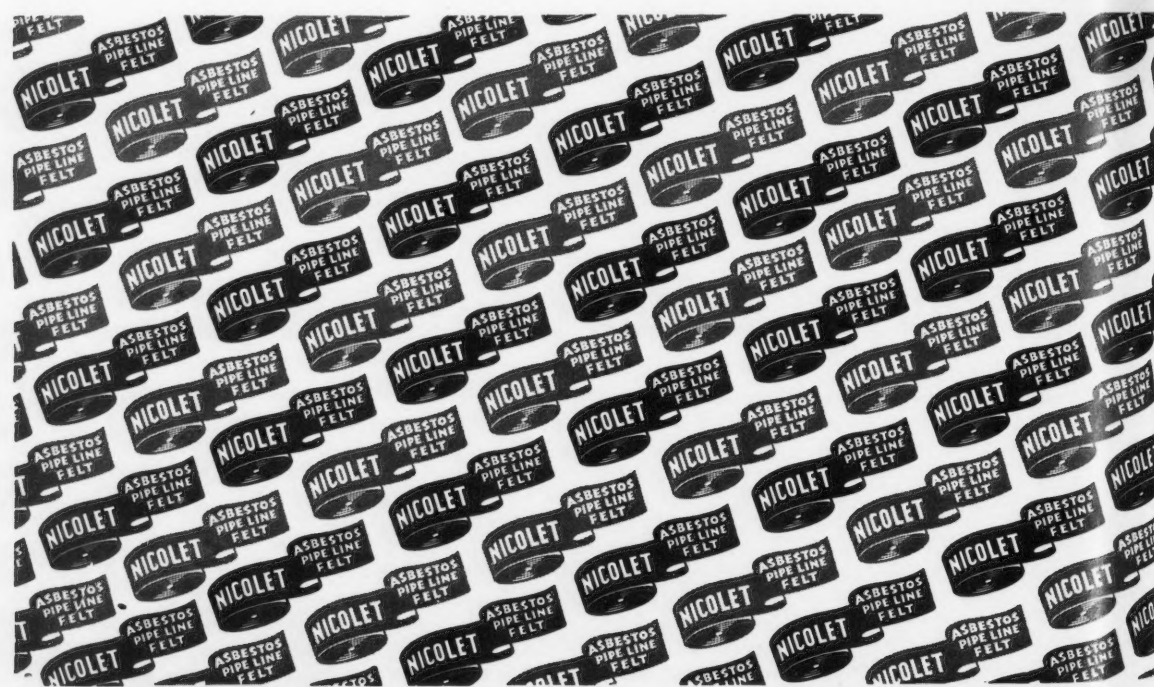
**Some Stepping Stones on the Path to the True Explanation of the Mechanism of Overvoltage.** ALFRED L. FERGUSON. U. S. Nat. Bur. Standards Circular, No. 524, 227-240, disc. 240-241 (1953).

The development of work on polarization and overvoltage is reviewed. Results obtained with refined equipment for hydrogen overvoltage for a number of materials and current densities are listed. The results and conclusions drawn from experiments on overvoltage values and decay curves under various conditions of current density, quantity of current passed, agitation, saturation with hydrogen or nitrogen, method of testing, &c., are discussed. 6 references.—MA. 7725

#### 3.6.9, 7.7, 7.2, 5.4.5

**The Protection of Buried Cables and Pipes Against Stray Currents by Means of Insulating Layers.** (In German). FRITZ AND WILHELM GLANDER. *Z. Metallkunde*, 44, No. 3, 97-101 (1953).

The origin of stray currents and their effect on the corrosion of buried metals is



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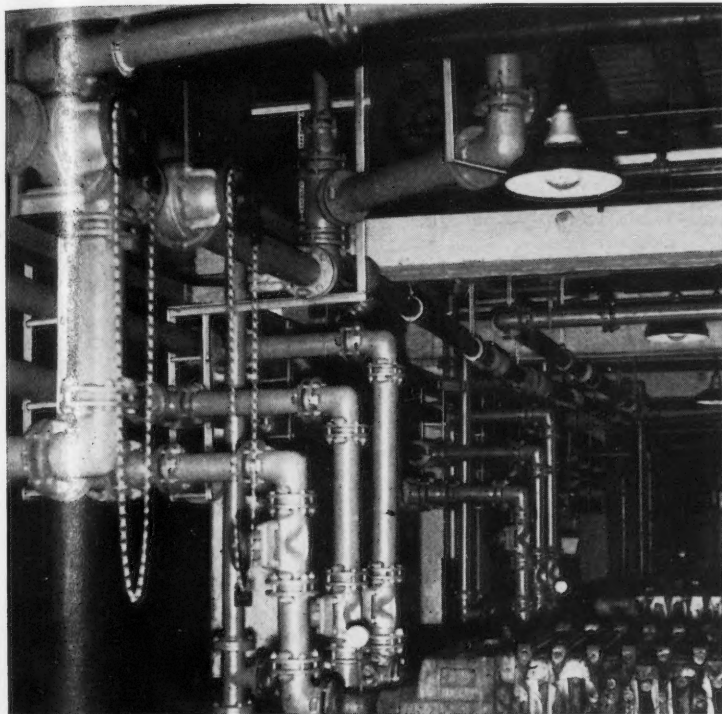
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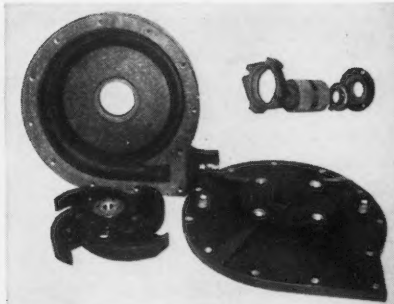
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discussed. Various precautions are taken in practice, e.g. avoidance or reduction of stray currents at the source, "electrical drainage", and cathodic protection. Protection of the cables and pipes with an insulating layer has the advantage that no investigation in the system of buried cables and pipes is required. The mechanical, chemical, and physical requirements of insulating materials are discussed; bituminous materials are not adequate after storage in moist conditions, but satisfactory results have been obtained by the repeated dipping of different types of cable in a special composition based on tar, which is not specified. An insulation resistance of  $10^{-10}$   $\Omega/\text{dm}^2$  is claimed.—MA. 7717

### 3.7 Metallurgical Effects

#### 3.7.2, 6.5

**High Purity Metals.** DANIEL J. MAYKUTH. *Product Eng.*, 24, No. 11, 186-190 (1953) Nov.

Minor impurities often control and occasionally obscure the true properties of metals. The properties and uses of high purity zinc, aluminum, iron molybdenum, chromium, titanium and zirconium are given. Pure metal exhibits maximum electrical conductivity, magnetic permeability, corrosion resistance and ductility along with minimum yield and tensile strength. Contaminating elements increase the strength but generally at the expense of other properties. Dissolved impurities tend to exert a more potent effect than those which show no solubility. In this respect non-metallic elements such as carbon, boron, oxygen and nitrogen are more difficult to eliminate and have a greater effect on properties than do dissolved metallic elements.—ALL. 7787

#### 3.7.3, 1.3, 5.3.2, 6.2.3

**Resistance Welding of Coated Steels—A Review of Information.** J. E. ROBERTS. *Brit. Welding J.*, 1, No. 5, 233-237 (1954) May.

A review of the published information on the resistance welding of steels with surfaces protected by metallic coatings. Cadmium-plated steel, lead and terne plate, tin and tin-alloy plated steel, aluminum-clad steel, zinc-coated steel, and copper-plated steel are considered. Information is mainly on spot welding. Tables of spot welding data for the various coated steels are presented. 17 references.—INCO. 7743

#### 3.7.3, 3.2.2

**Stabilizing Austenitic Chrome-Nickel Weld Metal Against Intergranular Corrosion.** HALLOCK C. CAMPBELL. Arcos Corporation, Philadelphia. *Welding J.* (N.Y.), 32, 577s-584s (1953) Dec.

Chromium and titanium additions to 18% chromium-8% nickel weld metal, for protection against intergranular attack, are satisfactory substitutes for the usual addition of columbium, which is in short supply. A 22% chromium-10% nickel electrode composition is proposed for field testing as a substitute for the standard Type 347 electrode for applications requiring resistance to intergranular corrosion. Screening tests, in which all-weld metal specimens in the as-welded state and in several heat-treated states were subjected to accelerated corrosion tests in boiling 65% nitric acid and in mixed nitric-hydrofluoric acids at 180°F., showed low corrosion rates for this composition both in the as-deposited condition and also after the four conventional heat treatments, including sensitization at 1200°F. for 1 hour. The room-temperature tension

properties were superior to the highest requirements of the AWS-ASTM electrode specifications. Tensile strengths increased with alloy content whether as-welded or heat-treated. All of the compositions exhibited good ductility under all conditions studied. Vanadium was unsatisfactory as a stabilizing element. Titanium was less effective than chromium.—PDA. 7713

#### 3.7.3, 5.3.4, 5.3.8

**Fatigue Tests of Steel Specimens Prepared for Metallizing.** R. C. MILLER, JR. AND A. W. BRUNOT. Gen. Elec. Paper before AWS Nat'l. Spring Mtg., Buffalo, May 4-7, 1954. *Welding J.* (N.Y.), Research Suppl., 33, No. 6, 275s-279s (1954) June.

Effect of several surface preparation procedures on the fatigue resistance of steel shafts was determined. The rough threading method is least damaging, with grooving and roughening next. Electrode roughening and metallic spray bonding are less desirable from the standpoint of strength reduction of parts which are subject to fatigue stresses. Rough threading shows a slight improvement in fatigue strength, but grooving and roughening provides more consistent and higher deposit bond strength. Shot peening is more effective than enlarging the radii at the ends of the preparation undercut as a method for improving the fatigue resistance of metallizing preparation. The base material investigated was AISI-4142 chromium-molybdenum steel bar, hot-rolled, heat-treated, machine-straightened and stress-relief annealed. Tables.—INCO. 7871

#### 3.7.3, 6.3.6

**Measurement of the Variation of the Free Energy of a Metal (Copper) During Cold Working.** ROGER JOUTY. *Compt. rend.*, 237, No. 9, 488-489 (1953).

The energy stored in a metal by cold working was measured electrochemically by studying the electromotive force of a cell of the type: Annealed metal/solution of a salt of this metal/cold-worked metal, using high-purity copper. Certain precautions were necessary to ensure reproducible conditions for the experiments. Taylor and Quimby [*Proc. Roy. Soc. (A)*, 143, 307 (1933)] gave values of the order of 0.3-0.6 cal./g. for cold-worked metal; but the more recent experiments of Eugène [*Compt. rend.*, 236, 2071 (1953)] gave much lower values, of the order of 0.01 cal./g. The results of the present experiments, although somewhat variable, gave a value of 10  $\mu$  V. for the e.m.f. of copper rolled to 80% reduction, which corresponds to 0.4 cal./g.-atom or 0.007 cal./g., in good agreement with Eugène.—MA. 7783

#### 3.7.4

**Grain Growth in Metals.** (In French). P. LACOMBE. *Métallurgie: Corrosion Industries*, 28, No. 338, 377-391 (1953) Oct.

Discussion of primary, continuous and discontinuous (or secondary) grain growth. Author concludes that discontinuous growth results from the inhibition of continuous growth by a separate phase or by a preferred orientation; the effects of mechanical working and heat treatment deserve further study.—BNF. 7816

#### 3.7.4, 6.2.1

**Influence of Internal Grain Structure of Austenite on the Self Diffusion of Iron.** (In Russian). P. L. GRUZIN AND E. V. KURDIUMOV. *Doklady Akad. Nauk SSSR*, 93, No. 6, 1021-1023 (1953) Dec. 21.

Discusses effect of internal grain structure in investigating diffusion mechanism in alloys where there are phase transformations. Graph. Six references.—BTR. 7718

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#### 4. CORROSIVE ENVIRONMENTS

##### 4.6 Water and Steam

4.6.1, 5.10

Perspectives: Design and Development. (Gadgets Alleged to Prevent Corrosion). *Product Eng.*, 24, No. 11, 123, 125 (1953) Nov.

An attack on various gadgets alleged to control scaling or corrosion in water pipes, which are sold on a large scale in U. S. A., although they do not operate in any known scientific manner.—BNF. 7820

4.6.6, 7.2

Corrosion Studies. JOHN R. BAYLIS. *J. New Eng. Water Works Assoc.*, 67, 38-73 (1953) March.

Factors affecting the corrosion of cast-iron pipe and the life of coal-tar coatings were studied. Unprotected cast-iron pipe corrodes in most domestic natural water supplies but not to the extent of materially weakened strength such as is noted with wrought-iron and steel pipe. The chief damage is the increase in friction loss from tuberculation. Calcium carbonate is the only known permanent natural coating for iron pipe. It can, however, be maintained only when the water is constantly saturated or slightly supersaturated with calcium carbonate. Unfiltered Lake Michigan water does have just the right pH for such ideal carbonate balance; uncoated cast-iron pipes carrying unfiltered Lake Michigan water have lasted 70-100 yr. Chemical treatment and filtration of Great Lakes water, without restoring it to the original pH, does, however, increase its corrosiveness to the extent that the calcium-carbonate coating is dissolved. Hot-dip coal-tar coatings on cast-iron piping exposed to raw Lake Michigan water generally are blistered and disintegrated but are still giving good protection after 30-50 years. Portland cement mortar gives promise of being much more durable than coal tar for lining cast-iron pipe.—PDA. 7685

4.6.11, 6.2.2, 1.4, 2.2.7

Behaviour of Cast Iron in Sea Water. An Annotated Bibliography. British Cast Iron Research Association. *Bull. Brit. Cast Iron Res. Assoc.*, 12, No. 1, 8-14 (1953) July.

Twenty-three references are given under corrosion and nine under test procedures, with abstracts of varying lengths.—BNF. 7638

##### 4.7 Molten Metals

4.7, 6.2.4

Dynamic Corrosion of Steel by Liquid Bismuth. O. J. ELGERT AND C. J. EGAN. U. S. Atomic Energy Comm., MTA-12, Jan. 6, 1953, 21 pp.

Feasibility of containing molten bismuth in a dynamic system at 1290°F in 5% chromium-½% molybdenum steels has been indicated with the use of about 100 ppm titanium plus 350 ppm magnesium as additives. Penetration rates below 20 mils/yr. can be attained at these operating conditions. Pre-oxidation of steel will reduce the corrosion rate of "500" type steels to 100 mils/yr. at 1290°F, but this is not considered a satisfactory solution to the corrosion problem due to the danger of chipping or eroding the oxide film. No correlation between chromium

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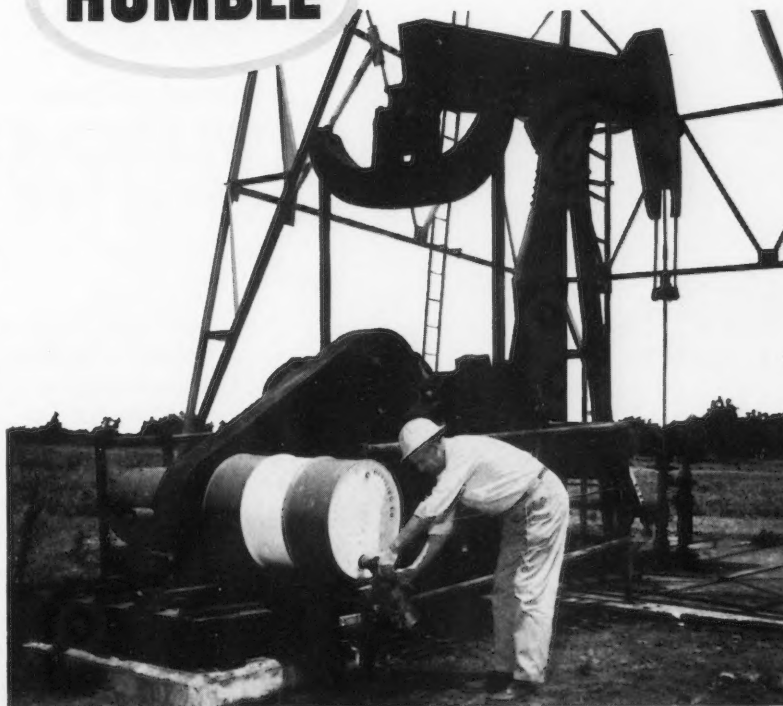


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content (steels with up to 12% chromium were tested) and penetration rates was noted. Tables, photomicrographs, and 7 references.—INCO. 7735

## 5. PREVENTIVE MEASURES

### 5.2 Cathodic Protection

#### 5.2.1

**Scope and Development of Cathodic Protection.** K. A. SPENCER AND D. A. LEWIS. *Corrosion Prevention & Control*; 1; Nos. 1, 2, 3 & 4; 15-21; 77-82; 155-158, 165; 221-223 (1954) March, April, May & June.

Development of cathodic protection and its principles are reviewed. Preliminary surveys of soil resistivity and of existing structures, including metal-electrolyte potential measurements, current flow, and coatings and protective current requirements are covered. Various cathodic protection applications include pipelines, tank bottoms, gas holders, and ships. Cathodic protection equipment, including instruments, electric supply equipment, and anodes are described. Economic advantages are also covered. Graphs and 18 references.—INCO. 7614

#### 5.2.1

**Anodes Vs. Rectifiers.** H. C. VAN NOUHUYS. *Petroleum Engr.*, 26, D-56—D-66 (1954) May.

Detailed report showing test data and economic advantage of rectifiers over anodes in high resistivity soil. Remote electrode method of measuring potential is used and a change of 0.3 volt is taken as criteria of protection. 7609

#### 5.2.1

**Cathodic Protection of Steel and Iron Against Corrosion.** (In German). HEINRICH KLAS. *Stahl u. Eisen*, 73, No. 15, 971-974 (1953) July 16.

The conditions for effective cathodic protection, and methods of estimating the required protective current, are discussed. The most important factors are the difference in potential between the anode and cathode, the surface condition of the component to be protected, and the electrical conductivity of the electrolyte. If an external current is applied, iron or steel scrap or graphite will serve as anodes; for galvanic anodes, only zinc, magnesium, aluminum, and their alloys are of practical importance. The required protective current, or the rate of consumption of galvanic anodes, may decrease with time, if protective layers formed on the cathodic areas increase its contact resistance with the electrolyte. Thus the effective and economic protection of any particular installation requires considerable thought and preliminary development work.—MA. 7755

#### 5.2.1

**Systematic Approach to Corrosion Mitigation.** MARSHALL E. PARKER. *Oil Gas J.*, 52, No. 26, 116-118 (1953) November 2.

The author asks ten questions and discusses the answers to each question, and if these questions are faced in the proper order, a systematic solution can be found to given cases with a minimum of effort. The ten questions answered in the article are: 1. Is the structure subject to corrosion?; 2. Is the corrosion serious enough to constitute a problem?;

3. Can cathodic protection help?; 4. What steps are necessary or advisable in conjunction with cathodic protection?; 5. How much current is required?; 6. Which system of cathodic protection is the better?; 7. How shall the drainage points be distributed over the structure?; 8. What size anodes should be used, and for what life should they be adjusted?; 9. What installation features are desirable?; 10. What is the recommended inspection and maintenance program? The discussion in this article is limited to corrosion involving buried structures of metal of which pipe lines form a prime example. 7793

#### 5.2.1, 8.9.3, 1.2.5

**Watch that Arc! It's a Hazard in Cathodic Protection Cables.** MARSHALL E. PARKER. *Oil Gas J.*, 52, 97, 119 (1953) Sept. 7.

Emphasizes danger of cutting a pipeline carrying a current. Suggests installation of a temporary bond across any joint to be broken, so arranged that it can be opened at a location free from dangerous vapors. Diagrams.—BTR. 7795

#### 5.2.2

**Cathodic Protection with Zinc Anodes.** Brochure, June, 1953, 49 pp. Published by the American Zinc Institute, 60 East 42nd Street, New York 17, New York.

Merits, of zinc anodes (compared with magnesium anodes and with rectified systems) in a variety of applications including distribution piping, transmission pipes, heat exchangers and condensers. Practical details, field trials and "case-histories." Intended as a supplement to the report entitled "Zinc as a Galvanic Anode." 7662

#### 5.2.2, 7.3

**Cathodic Protection and Magnesium Anodes: Application to Pumps.** (In French). B. RACLOT. *Metaux: Corrosion-Industries*, 28, No. 335/336, 319-322 (1953) July-August.

The location of magnesium anodes with a view to affording a system of cathodic protection to under-water pumps having either vertical or horizontal shafts, is discussed. The complete protection of the elements of a pump, having a vertical axis, immersed in soft, bacterial water for a period of two years required 5 magnesium anodes weighing 0.400 kg. and 1 anode weighing 17 kg.; the use of steel or special alloys would have produced a result 10 times as satisfactory.—MA. 7796

#### 5.2.3

**How to Select Size of Rectifier Cable.** M. E. PARKER. *Oil Gas J.*, 52, No. 24, 161 (1953) October 19. 7792

### 5.3 Metallic Coatings

#### 5.3.2

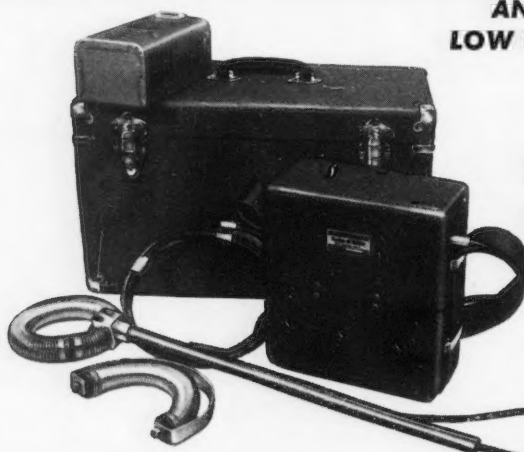
**Crack-Free Chromium from Baths of the Self-Regulating High-Speed Type.** R. DOW AND J. E. STARECK. *Plating*, 40, No. 9, 987-995, disc. 995-996 (1953); (abridged) *Metal Ind.*, 83, No. 17, 342-344 (1953).

Results of comparative tests on crack-free chromium deposits and ordinary chromium plate are discussed. Details are given of the improvement in corrosion-resistance obtained with the imper-

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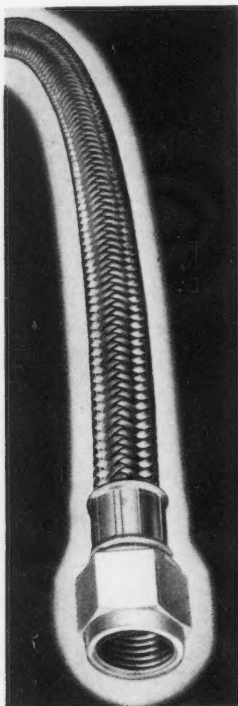


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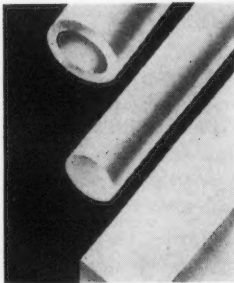
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vious plate from baths of the self-regulating, high-speed type. In addition to improved resistance to thermal stress, there are indications from preliminary tests that these deposits have advantages over ordinary plate with respect to hardness, levelling action, and ability to withstand externally applied stress.—MA.

7741

#### 5.3.2

**A Comparison of the Fields of Application of Electrolytic and Hot Dipped Tinplate.** W. R. LEWIS. *Metallurg. Corrosion Industries*, 28, No. 332, 175-183 (1953).

Methods of manufacturing tinplate by the electrolytic (E) and hot-dip (D), processes are reviewed, and the pros and cons of the respective products are compared. The principal disadvantage in the finished plate, in either case, is the presence of pores. The significance of porosity and troubles associated therewith are discussed; the thickness of tin coating of D-type plate is 2-5 times as much as that in the E type. D plate possesses more marked orientated-grain characteristics than E plate; nevertheless, there does not appear to be any reason for preferring E-type plate for subjection to drawing and cutting operations. Good-quality D plate is ideal for soldering; soldering defects occur with both types of plate; the steel base is in both cases the cause of the trouble, and is associated with the subjection of the steel to normalization. The same types of lacquers are used for both types of tinplate; adherence is satisfactory in both cases. It is too early yet to express a preference for any special type of E plate in relation to its mode of preparation, whether tinned in an acid or alkaline bath, the method of polishing, whether passivation is achieved in chromic acid or sodium dichromate. Lacquering does not constitute a good remedy against corrosion; lacquered tinplate containers in contact with corrosion products are liable to perforation. It is necessary therefore that the thickness of tin coating used on E plate coming in contact with corrosive products should have a thickness of 1.6  $\mu$ , compared with customary thicknesses of 0.4-0.8  $\mu$ , supplemented to a small extent with 1.2  $\mu$  coatings. A small amount of the 1.6  $\mu$  product is available in the U.S.A., but, up to now, plant is not available for its manufacture at an economic speed. Differences between one lot of E plate and another are due principally to differences, both chemical and physical, in the nature of the steel surfaces upon which the tin is deposited. Preservation and the total weight of tin available seem to be related; this appears to be confirmed by results using tins constructed partly of D and partly of E plate. Prices are quoted showing that the cost of E plate is ~ 88% of that of D plates, but this figure must not be considered either constant or definitive.—MA.

7832

#### 5.3.2, 2.3.7

**An Evaluation of the Preece Test.** H. BABLIK, F. GOTZL AND E. NELL. *Metall. Oberflache*, 7, No. 5, A66-A72 (1953) May.

The Preece test for galvanized coatings measuring the time taken to dissolve the zinc coating in copper sulphate solution is investigated. The test is inaccurate for determining coating thicknesses due to the variations in potentials of zinc produced under different conditions. Its

# How corrosion is controlled in making a famous Chlorinated Organic Weed-Killer

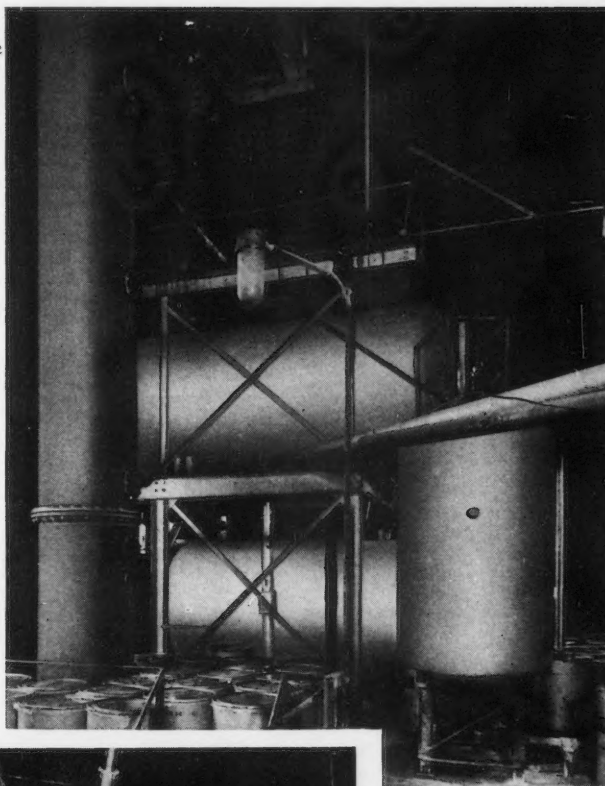
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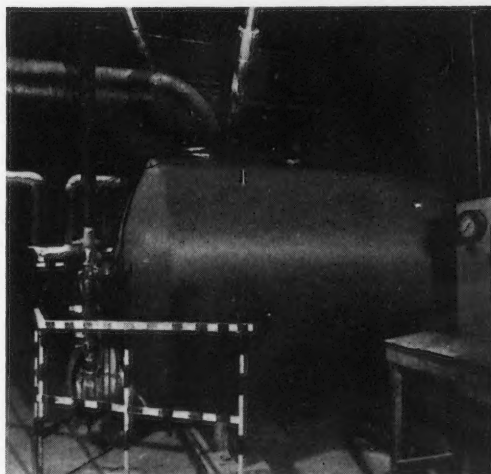
Small amounts of hydrochloric acid form during chlorination, and, together with unreacted chlorine, constitute a corrosion thread which persists through the distillation stage. And beyond the fractionation stage, even small amounts of corrosion products, if allowed to form, will affect color and purity.

When operations were still in the pilot plant, trouble was experienced with corrosion of certain equipment items. Inco's Corrosion Engineers were called in and corrosion tests were performed at various equipment sites. As a result of the tests, nickel pipe and fittings were installed in the system and eventually the use of Nickel and Nickel-Clad Steel was extended to such important items as the still, steam coils, fractionating tower, condenser and storage vessels used in making and handling dichlorophenol.

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present use is thus restricted to testing uniformity of newly formed coatings produced by the same process.

The investigation was intended to show the varying potentials of the individual layers in a galvanized coating and to demonstrate their differing rates of solution. These are given for the various iron/zinc phases and it is shown that oxide layers can greatly inhibit attack according to their thickness and porosity. Impurities in the zinc do not appear to exert much influence. The specimens were Armco iron sheets galvanized by various methods. 7651

### 5.3.2, 6.4.2

**How Tough Are Nickel and Chromium Electroplates for Aluminium?** H. PAIGE, J. H. JAMES AND F. S. WILLIAMS.

*Product Eng.*, 24, No. 12, 162-167 (1953) Dec.

As a means of increasing the application scope of high strength aluminum alloys, electroplating techniques are attracting considerable attention. Among the promising electroplates for aluminum are nickel and chromium. As hard surface deposits, they permit the application of aluminum alloys where weight reduction, without sacrifice in strength as wear resistance, is necessary to design. The value of nickel and chromium electroplated high strength aluminum has been revealed in a series of corrosion and mechanical strength studies conducted by the U. S. Navy Bureau of Aeronautics. The electroplated specimens for which mechanical strength properties were obtained were both unexposed and

exposed to corrosive conditions of salt spray and atmosphere. In general, no substantial changes in ultimate tensile and yield strength were exhibited in unexposed nickel and chromium plated specimens up to about 8 mils in plated thickness. Heavier deposits, however, with the exception of Pinner nickel, displayed a reduction in ultimate strength based on plated diameter. In salt spray and atmospheric exposure tests, the 2-mil chromium 0.2-mil nickel duplex plating displayed the most outstanding corrosion resistance. It is evident that hard nickel and chromium electroplates for aluminum have certain merit, because of the improved corrosion resistance offered by the nickel plate and the outstanding corrosion resistance exhibited by the duplex coating.—ALL. 7876

### 5.3.3, 2.5

**Electroplated Coatings of Nickel and Chromium.** British Standard No. 1224, 1953, 14 pp. British Standards Institution, 2 Park Street, London, W. 1.

Revision of standard first published in 1945, was undertaken principally to meet the requirements of the automobile industry. A thicker coating of nickel on steel, and coatings on zinc alloys have been included; attention is drawn to the effect of contour. Scope; definitions; sampling; finish, thickness, adhesion, salt spray testing and heat treatment of nickel coatings (on steel, copper, copper alloys, zinc alloys, aluminum and aluminum alloys); finish, thickness and heat treatment of chromium coatings (on nickel plate or stainless steels); testing methods.—BNF. 7676

### 5.3.4

**Metallising Non-Metallic Surfaces.** *Product Finishing*, 6, No. 11, 74-78 (1953) November.

A brief review of the five main methods at present available for applying metallic finishes to non-metallic surfaces such as ceramics, glass and plastics. Some details are also given of the types of metallized coatings that may be produced, together with notes on their chief applications. Three of the methods described are in general use for applying zinc to such surfaces.—ZDA. 7811

### 5.3.4

**Graphical Calculation of Metallic Electrodeposits.** (In French). J. BREUIL. *Chimie et Industrie*, 70, No. 2, 208-212 (1953) August.

Nomograms for calculating the thickness of metal deposited, the total current required, the voltage, etc., for a given current density, and current efficiency, for all the usual metals.—BNF. 7654

### 5.3.4, 6.4.2, 7.4.2, 3.4.8

**Corrosion of Aluminum Condensers in a Bath for the Electrodeposition of Zinc.** A. I. LEVIN, A. V. POMOSOV, AND T. N. ROGATKINA. *Zhur. Priklad. Khim.*, 26, 1245-1251 (1953) December. (In Russian).

The rate of corrosion of aluminum in a bath for the electrodeposition of zinc is dependent on many factors and especially on the presence of impurities in the electrolyte. The effect of various impurities, such as  $\text{Cu}^{+2}$ ,  $\text{Sb}^{+3}$ ,  $\text{Pb}^{+2}$  [ $\text{SiCl}_4$ ],  $\text{Fe}^{+3}$ ,  $\text{F}^-$ ,  $\text{Cl}^-$ , or  $\text{NO}_3^-$ , is tabulated. Extensive data are given on the corrosive effects of  $\text{F}^-$  and sulfuric acid. The corrosion behavior of aluminum changes with its position in the electrolytic bath.—NSA. 7875



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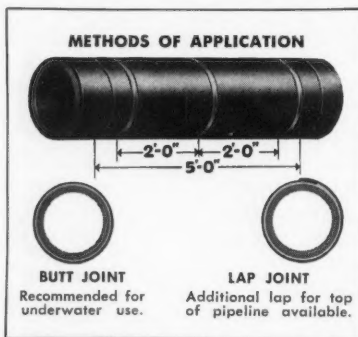
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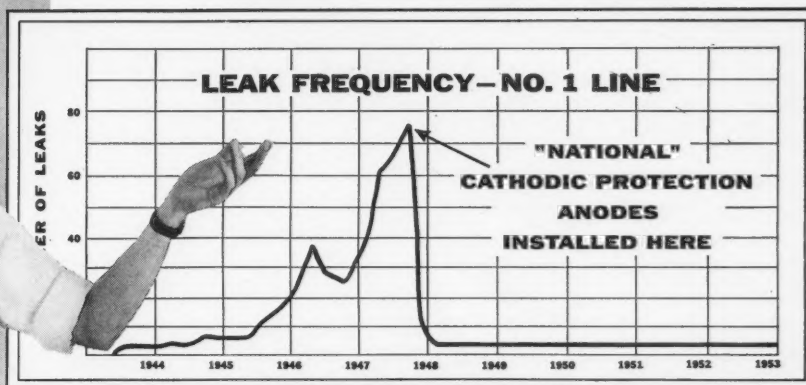
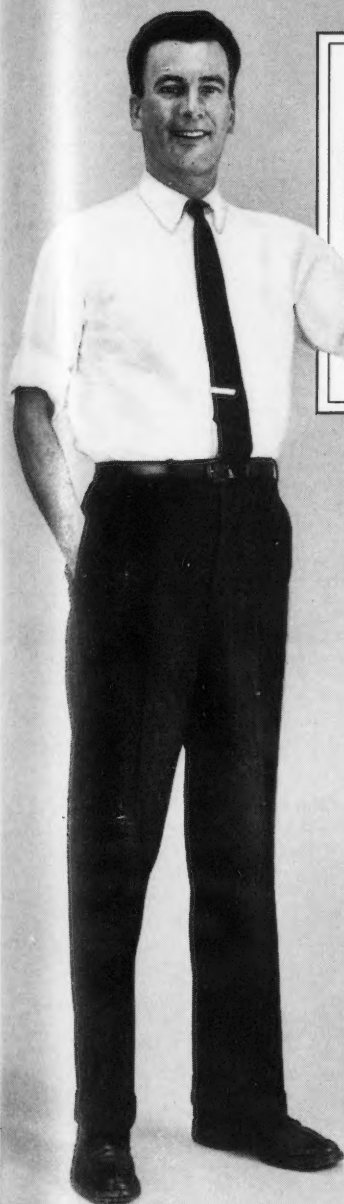


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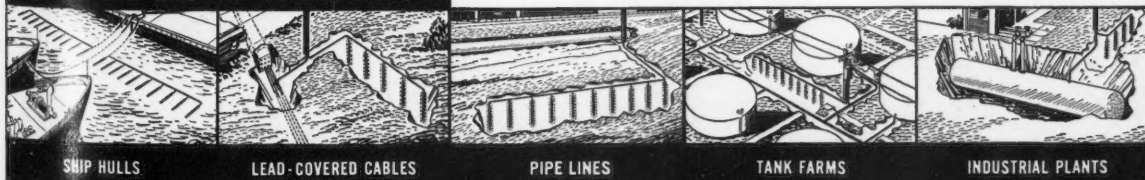
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## 5.3.4, 8.8.5

**Practical Galvanizing.** (In French). G. HAAS AND A. GORDET. *Galvano*, No. 197, 16-18 (1953) June.

A number of schemes for preventing the molten zinc attacking the bath are discussed. Among these are lining with graphite or cement fondu, spraying with aluminum, the use of a shallow layer of zinc floating on a large depth of lead and installation of an inner pot. None seems perfect, but the authors suggest that with careful operation a life of five or six years should be obtained from a conventional bath.—ZDA. 7706

## 5.3.4, 8.8.5

**Difficult Galvanizing Jobs Done in New Radiant Furnace.** R. C. BOHNKE. *Ind. Heating*, 20, No. 9, 1702, 1704, 1706, 1842 (1953) Sept.

Radiant gas burners can be placed close to pot walls without flame impingement. Temperature uniformity is improved, maintenance costs reduced and pot life increased. Furnace is used for galvanizing sheet metal burial vaults.—BNF. 7674

## 5.4.5, 2.3.1, 5.9.1, 5.4.6, 1.7.1

**Fifty Years of Paint Testing.** 47 pp., 1953. American Society for Testing Materials, 1916 Race Street, Philadelphia, Pennsylvania.

This booklet is a collection of reports on paint testing by the members of ASTM Committee D-1. The separate subdivisions of the committee report on their history and achievements and indicate their route of future inquiry. Topics covered by the subcommittees are: Drying oils, bituminous emulsions, volatile hydrocarbon solvents for organic protective coatings, accelerated tests, methods of chemical analysis of paint materials, varnish, optical properties, resins, exterior exposure testing on wood, shellac, pigment specifications, printing inks, flash point, physical properties of materials, cellulosic coatings and related materials, protection of iron and steel. Some of the reports include extensive data.

The last report on the protection of iron and steel relates and illustrates with graphs and tables the committee's experience in a testing program designed to evaluate the treatment of steel with cold phosphate treatments. This work, initiated in 1937, resulted in accumulation of data which indicated that performance of panels with mill scale intact was as good as that of panels sand-blasted before retreatment. Panels wire-brushed after rusting gave very short paint life under all conditions.

The committee is now investigating the economic aspects of repainting, seeking to determine when repainting will be best from a long-term cost standpoint. The subcommittee's work also has been broadened to include an investigation of preparation of aluminum and magnesium surfaces for painting. Another group is preparing 40 colored pictures showing the classification of ferrous surfaces for painting. 7697

## 5.3.4

**Electrodeposition of Tin-Zinc Alloys.** B. C. LEWSEY. *Electroplating*, 6, No. 11, 411-415 (1953) Nov.

Experience has shown that the process of electrodepositing tin-zinc alloys requires rigid and continuous control. Other constituents remaining constant, caustic content plays by far the most important part in deciding the composition of the deposited alloy. With a zinc concentration of 2.5 g./l. and total cyanide 27-29 g./l., alloys containing 15-30% zinc are deposited with caustic contents ranging from 5.5 to 11 g./l. A rubber-lined vat is best and great care must be taken to prevent steam pipes or other metallic connections from becoming anodic or cathodic. The anode current density should not be less than 15 amp./sq. ft. to maintain filming of the anodes.—ZDA. 7745

## 5.4 Non-Metallic Coatings and Paints

## 5.4.5, 6.4.2

**A Coating for Aluminum Has Excellent Adhesion and Corrosion Resistance.** *Materials and Methods*, 38, No. 6, 102 (1953) December.

The Connecticut Hard Rubber Company has developed a method whereby aluminum can be covered with a fluorocarbon plastic coating called Kel-F, the thickness of which ranges from 0.005 in. upwards, the optimum being approximately 0.010 in. This coating is applied with such a temperature and time combination in its treatment that the physical and chemical properties of the aluminum and the plastic are substantially unchanged. The coating, applied from a dispersion, has no pin holes and is so tightly bonded to the metal that it cannot be peeled or stripped. In addition, tests by the company have shown that lengthy exposure to highly corrosive agents will not blister or lift the film. The coated metal can be bent and deformed without rupturing or damaging the protective coating, which presents obvious manufacturing advantages, in that a sheet of aluminum may be coated first, then drawn or formed to the desired shape. This process is adaptable to parts of all reasonable size and shape, and even tubes of intricate configuration can be successfully coated, inside or out. Kel-F coated aluminum possesses approximately the same corrosion resistance properties as glass but eliminates the prohibitive breakage factor.—ALL. 7837

## 5.8 Inhibitors and Passivators

## 5.8.3, 4.3.2

**Action of Polar Organic Inhibitors in Acid Dissolution of Metals.** N. HACKERMAN AND A. C. MAKRIDES. *Univ. Texas. Ind. & Eng. Chem.*, 46, No. 3, 523-527 (1954) March.

Discussion of function of inhibitors by increasing the true ohmic resistance and by interfering with the anodic, the cathodic, or both the chemical processes is given. Theories of cathodic inhibition, inhibition and general adsorption, adsorption of polar organic inhibitors, and applications of the mechanism are discussed. 45 references.—INCO. 7687

## 5.8.4, 5.6.1

**Volatile Rust Inhibitors.** HAYWARD R. BAKER. *Naval Research Lab. (NRL-4319)*, March 10, 1954, 23 pp.

Volatile products highly effective in the inhibition of rusting have been found in a wide variety of organic amines and acids and in the reaction products of amine with acids, the latter being particularly effective. Varying degrees of protection of ferrous surfaces can be expected from suitable members of the following classes of compounds: aliphatic

or aromatic acids; primary, secondary, and tertiary amines; amine salts of weak inorganic acids; amine-organic acid complexes with organic acids; hydroxy-substituted aromatic acids and acid anhydrides; miscellaneous compounds such as nitromethane to nitropropane, morpholine, camphor, carbamides, and ammonium hydroxide; and any combination of compounds which on reaction yields any of the compounds mentioned in the series above. The association complexes formed by amines with weak acids hydrolyze or dissociate extensively to give volatile products capable of adsorbing on the surface to be protected. Inhibition is usually most effective in systems held at a pH between 7.5 and 8.5 and at a temperature that allows adequate vaporization of the inhibiting compound. Proper sealing against convective or diffusional loss of the inhibitor is essential. Detrimental effects due to humidity are minimized when these inhibitors are used in conjunction with silica gels. Because of possible corrosive injury by the vapor-phase rust inhibitor, certain nonferrous metals, such as cadmium and zinc, require special protection in the form of a plastic or waxlike spray that is impervious to the rust-inhibitor vapors. Volatile rust inhibitors have simplified the packaging, storage, and shipment of military equipment and replacement parts and have permitted immediate use of the packaged items without the tedious procedures normally associated with the removal of oil or grease preservatives before placing either stored or packaged equipment into service. Steel surfaces may be protected from rusting by simply wrapping the steel part with paper impregnated with the inhibitor crystals or by using inhibitor-coated paper as a liner for cartons or packages. Because of the economy and simplicity of these compounds and the techniques of their use, they are finding wide acceptance in military and industrial packaging procedures.—NSA. 7572

## 5.8.2, 8.4.3

**Here's a New Solution for Selective Absorption of Hydrogen Sulfide.** F. E. MILLER AND A. L. KOHL. Fluor Corp. Ltd. Paper before Pacific Coast Gas Assn., Los Angeles, Feb., 1953. *Oil Gas J.*, 51, No. 51, 175-176+ (1953) April 27.

Results of laboratory and pilot plant work show that methyldiethanolamine (MDEA) has appreciable selectivity for hydrogen sulfide in the presence of carbon dioxide. Commercial-scale test with MDEA carried out in a refinery plant which previously used diethanolamine showed no major evidence of corrosion after 20 weeks operation. Most severe corrosion of steel to the extent of 0.007 in. penetration per year occurred in the reboiler. 3-S aluminum coupons showed slight corrosion. Croloy 5 coupons were slightly more resistant than carbon steel. Type 304 stainless coupons, showed no detectable corrosion. Flow diagram, graphs, 4 references.—INCO. 7821

## 5.8.2, 8.4.3, 8.9.3

**Metals Corrosion: Inhibitors. Test for Presence and Evaluation of Product Soluble Rust Inhibitors.** P. L. DEVERTER. *Petroleum Engr.*, 25, No. 10, C35 (1953) Sept.

Method of test to evaluate rust inhibiting qualities of product soluble rust inhibitors for protection of pipe lines when added to gasoline or light oil.—EL. 7738





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## 5.9 Surface Treatment

### 5.9.2

**The Stripping of Plating Shop Rejects.** C. D. LEONARD. *Electroplating*, 6, No. 8, 290-292, 296 (1953) August.

General rules applying to the choice and operation of the stripping processes are given and problems such as layout, storage of components, cleaning before stripping, and control of the stripping process are discussed briefly. Details are given on the methods in commercial use for the most common combinations of metals and alloys. Zinc deposits on steel are usually removed in an inhibited hydrochloric acid solution; anodic treatment in caustic soda solution may also be used.—ZDA. 7758

### 5.9.3

**Shot-Peening.** *Ind. Finishing* (London), 6, No. 64, 182, 184, 186-187 (1953).

Shot-peening is described, and its differences from abrasive tumbling are explained. In addition to improving the fatigue-resistance of both ferrous and non-ferrous components, it has proved of value in combatting the stress-corrosion cracking of some light alloys, for reducing or eliminating porosity in aluminum alloy die-castings, and in the testing of the adhesion of plated metals, especially silver electrodeposits.—MA. 7782

## 7. EQUIPMENT

### 7.7 Electrical-Telephone and Radio

#### 7.7, 3.6.6

**Compression Solves Distribution Connections.** I. MATTHYSE AND H. P. DUPRE. *Elec. World*, 140, No. 12, 159, 162 (1953) September 21.

The recently developed C-shaped compression connector with an open side can be applied without cutting conductors. It maintains adequate contact pressure ensuring low contact resistance and anchors conductors against twisting, vibration and other stresses. The best structural shape of this "C" connector is with a relatively heavy wall thickness at the back of the C, tapering off towards the edges. Aluminum connectors are used for aluminum conductors, copper for copper. Test results show that a pull-out force of 700 lb. was obtained on a connector that joined 4/0 stranded to No. 2 solid aluminum conductors. The relative conductivity of joints remained virtually constant and above 100% for 400 hours of exposure in a salt spray fog (20% sodium chloride-solution) at 98°F. The connector temperature and the relative joint conductivity remained almost constant when load cycled to a conductor temperature of 100°C and the connector remained cooler than the 100°C conductor temperature throughout 54 load cycles of 1½ hours on and 1 hour off. In a new method for joining aluminum and copper the aluminum conductor is gripped in one end of an aluminum compression connector; the other end of this connector is pressed on the copper conductor. Tests of such joints between No. 4 stranded copper and No. 2 solid aluminum showed virtually no corrosion on the bimetallic juncture between a large aluminum mass (connector) and the smaller copper conductor. Very slight pitting appeared on the end of the aluminum connector adjacent to the copper conductor. Modifications of this principle permit connect-

ing aluminum risers to copper terminals on transformers and equipment.—ALL. 7574

### 7.7, 6.4.2

**Aluminum in Electrical Applications.** R. M. LEEDY AND S. A. ZOSECRANS. *Materials and Methods*, 37, No. 2, 89-96 (1953).

The replacement of copper with aluminum is accounted for on the basis of ease of availability and favorable price trend of the latter. The use of aluminum conductors is said to allow greater electrical loading combined with considerable weight-saving as compared with copper, even though the electrical conductivity of aluminum is only 61-63% that of copper on a volume basis. The greater thermal expansion of aluminum must be allowed for in applications where it is to be used to replace copper. Careful consideration must be given to such factors as strength, elongation, and creep rate. The necessary precautions of bolting, soldering, brazing, and welding aluminum are enumerated. The possibility of electrolytic corrosion of aluminum in contact with copper is stressed, and a number of precautions are indicated. The applications of aluminum for electrical purposes are discussed, with particular reference to transformers, reactor windings, generator windings, insulated cable for power distribution, and evaporator coils.—MA. 7763

## 8. INDUSTRIES

### 8.4 Group 4

#### 8.4.2, 6.2.3

**The Action of Crude Gas on Mild Steel.** L. A. RAVALLD. Paper before Inst. Gas Engrs., 19th Research Mtg., London. *Corrosion Prevention & Control*, 1, No. 2, 89-94, 104 (1954) April.

Long-term investigation of action of hydrogen sulfide, hydrogen cyanide, and ammonium thiocyanate on mild steel of aqueous conditions is reported. Results indicate that, at ordinary temperature and in oxygen-free conditions, either little corrosion occurs or, with hydrogen sulfide, a largely protective film of ferrous sulfide is formed. Effect of the presence of oxygen in promoting attack is significant. Results emphasize the damage that can occur to the interior of gas units when opened to the air, whereby any protective film of corrosion product is disrupted by oxidation. Corrosion problems concerning ammonia liquor concentration plants are also discussed, and the experience with experimental vapor condenser tubes of an aluminum alloy are described. Diagram, tables and graphs.—INCO. 7867

#### 8.4.3, 6.2.2

**When Can You Use Cast Iron in the Refinery?** W. J. BUXTON. *Oil Gas J.*, 52, 128-130, 132 (1953) Oct. 19.

Uses and limitations of cast iron in petroleum refining equipment. Photographs.—MR. 7672

#### 8.4.3, 7.4.2

**Practical Solutions to Five Common Corrosion Problems.** JOHN F. MASON. *Petroleum Processing*, 8, 1332-1335 (1953) Sept.

Discusses corrosion of poly-charge preheaters, crude fractionating tower tops, amine gas plant reboiler tubes. Linde gasoline treater eductors, and gasoline condenser equipment. Tables—BTR. 7826

## 8.7 Group 7

### 8.7.4

**Materials of Construction for Photographic Processing Equipment.** L. E. MUEHLER AND J. I. CRABTREE. Eastman Kodak Co. P. S. A. *Journal*, 19, Sect. B, 79-88; 92-104 (1953) May, August.

Factors in corrosion and types of corrosion in photographic processing are briefly considered. Detrimental effects of some metals and alloys on the processing solutions and processes are indicated. Outlines are given of qualitative corrosion and photographic tests of sample materials. Single metals including aluminum, copper, iron, lead, nickel, and titanium, and alloys including Nichrome, nickel silver, Monel, Ni-Resist, Inconel, Incoloy, and stainless steels of various types are listed according to relative resistance to corrosion in the photographic field. Inconel and austenitic stainless steels, such as Types 304 and 316 are the principle alloys which have been adopted for photographic use. Coated and clad metals are considered as well as non-metals such as quarried silicate rock, wood, and synthetic products including ceramics and glass, rubber and plastics. Tables and 116 references.—INCO. 7843

## 8.9 Group 9

### 8.9.2

**Corrosion of Automobile Bodies.** F. L. LAQUE. Inco. Paper before Society of Automotive Engineers Nat'l. Passenger Car, Body, and Material Mtg., March 3-5, 1953, Detroit. SAE Preprint No. 52, March, 1953, 7 pp.; *SAE Journal*, 61, No. 7, 78-80 (1953) July.

Problem of corrosion of automobile bodies is considered under three headings: the corrosive medium; composition of the metal; and design features. Most trouble from corrosion can be found in sea shore environments and in heavily industrialized communities. Salt treatment of roads, steels for automobile bodies and protective coatings are discussed. Most important design consideration is to insure that water cannot collect in pools and that all surfaces not only drain readily but are able to dry quickly. Illustrations and references.—INCO. 7786

### 8.9.3, 5.4.10, 5.2.1

**New Techniques and Current Problems in Control of Underground Corrosion.** O. C. MUNN. Shell Pipe Line Corp. Paper before API, Ann. Mtg., Chicago, Nov. 10, 1953. *Oil & Gas J.*; 52; Nos. 30, 31, 32 & 34; 99, 144, 159, 100 (1953) Nov. 30, Dec. 7, Dec. 14, Dec. 28; *ibid.*; 52; Nos. 37, 38, 40; 127, 285, 139-140 (1953) Jan. 11, Jan. 25, Feb. 8; *Gas Age*, 112, 46-51, 77-78 (1953) Dec. 17; *Proc. Am. Petroleum Institute, Sec. 1, Transportation*, 33, 35-45 (1953).

Author discusses use of thin-wall pipe, substitution of zinc rods for copper-clad rods for ground beds, use of coal-tar enamel and asphalt enamel coatings on small diameter lines, galvanizing steel structures to conserve protective current, electrical-current drainage, pipe line enamel tests, and use of asbestos as a protective wrapper over coating to prevent soil adhesion to the coating surface. Graphs and illustrations.—INCO. 7815

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American CH  
American Ha  
Association  
Apex Smeltin  
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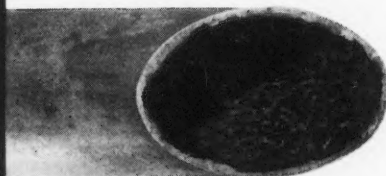
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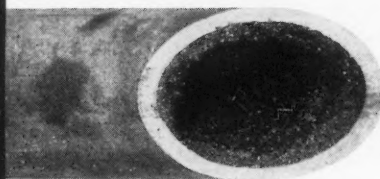




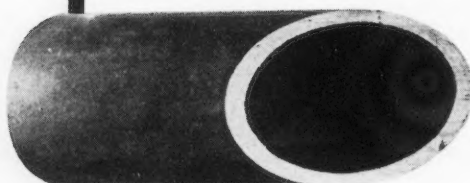
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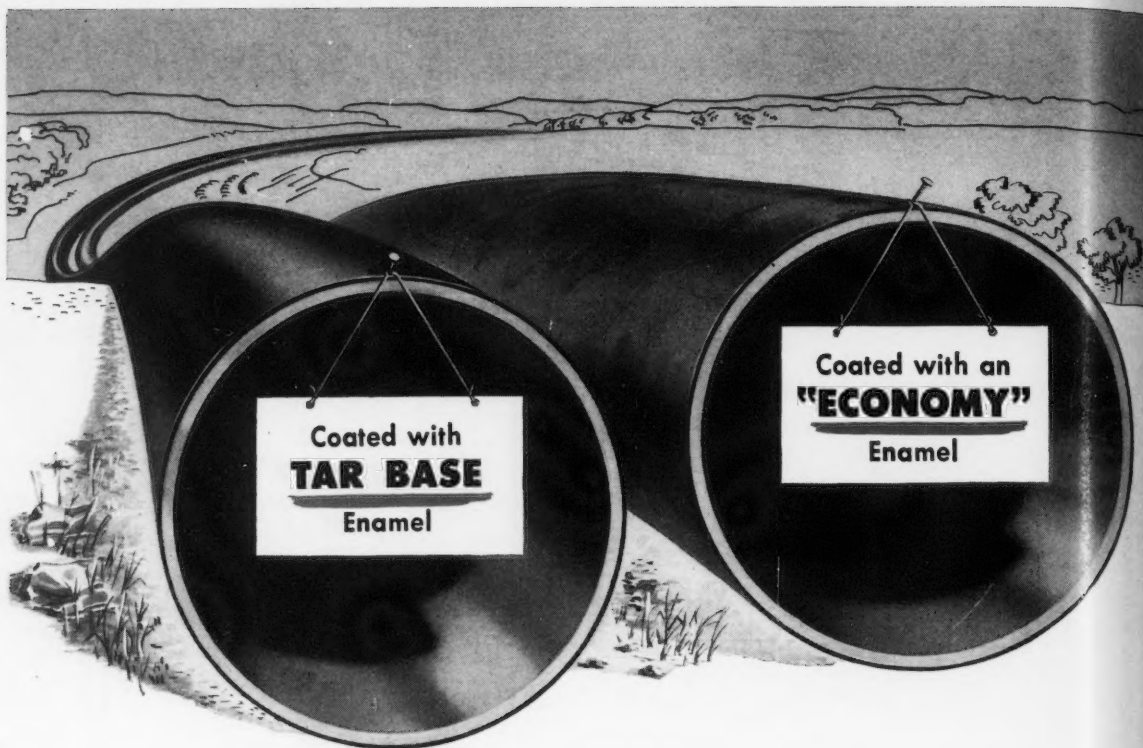
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